

The Association of State Wetland Managers. Inc.

Dedicated to the Protection and Management of the Nation's Wetlands

October 15, 1993

Executive Director

Jon A. Kusler, Esq.
Box 2463
Berne, NY 12023
518-872-1804

Chairman

Scott Hausmann
Wisconsin DNR
Box 7921
Madison, WI 53707
608-266-7360

Vice Chairman

Patricia Riexinger
New York DEC
50 Wolf Rd.
Albany, NY 12233
518-457-9713

Secretary-Treasurer

Richard Hamann, Esq.
University of Florida
230 Bruton-Geer Hall
Gainesville, FL 23611
904-392-2237

Board Members

Michael Aurelia
Greenwich Wetland Agcy.

John Banta
Adirondack Park Agcy.

Taber Hand
The Dodge Foundation

Marvin Hubbell
Illinois Dept. of Conservation

Robin Lewis, III
Lewis Environmental Serv., Inc.

R. Terry Huffman
Huffman and Associates, Inc.

Ken Bierly
OR Div. of State Lands

Pat Parenteau
Perkins & Coie, Inc.

Kevin Erwin
Kevin Erwin Cons. Ecologist

DEAR SPEAKER, PANELIST, PARTICIPANT:

RE: Post Flood Recovery in the Mississippi Basin: Options and Opportunities to Prevent Future Flood Losses, August 30-31, 1993

The Association of State Floodplain Managers and The Association of State Wetland Managers have prepared draft recommendations from the August 30-31 and September 27-29 meetings in St. Louis that we have submitted to the White House. Please submit any comments or changes pertaining to those recommendations to us by October 21, 1993. What has been left out? What should be changed? We expect to submit a revised list of recommendations to the White House, federal agencies, and Congressional Committees by November 1, 1993.

We are also preparing a revised "source book" of materials for groups and individuals who were not able to attend the meeting but interested in post disaster response and the restoration of floodplain areas including wetlands and riparian zones. We expect that preparation of this collection of papers and materials will be funded, in part, by the National Fish and Wildlife Foundation. This source book will include all or virtually all of the materials provided to participants at the meeting. It will also include additional papers submitted to us by speakers, panelists, and participants. So, if you want your paper or other materials included in this revised source book, please get them too us in reproducible form by October 21, 1993.

We are also hoping to facilitate several follow-on activities:

--A meeting dealing with agriculture and wetlands. Mark Beorkrem of the Quad City Environmental Coalition has expressed an interest in hosting and organizing such a meeting (if funding support can be found).

--A meeting dealing with community floodplain and waterfront restoration programs including "buy-outs", relocation, floodproofing, and greenways. Tentative dates are December 7-10 in Davenport, Iowa.

Please join us in urging the White House, federal agencies, Congress, the states, local governments, and interest groups to help implement the recommendations from these meetings.

Thanks again. We really appreciate your help.

Sincerely,



Jon Kusler

Box 2463 Berne, NY 12023-9746 518-872-1804 Fax: 518-872-2171

Preliminary (October 1, 1993)

Post Mississippi Basin Flood Response, the Mitigation of Future Flood Losses, and the Restoration of Floodplain, Wetland, and Riparian Zones

RECOMMENDED IMMEDIATE ACTIONS BY THE WHITE HOUSE, FEDERAL AGENCIES, AND CONGRESS

**Association of State Wetland Managers
Association of State Floodplain Managers**

Prepared by

**Jon Kusler, Executive Director, ASWM
Larry Larson, Executive Director, ASFM**

The following recommendations for immediate actions are derived from two workshops concerning post flood response from the upper Mississippi basin 1993 summer flooding and mitigation of future flood losses. The workshops were jointly conducted by the Association of State Floodplain Managers and Association of State Wetland Managers with a broad range of cooperating organizations in St. Louis, Missouri, August 30-31, 1993 and September 27-29, 1993. These workshops involved over 300 participants from the states, local governments, universities, federal agencies, and interest groups. The first workshop focused generically upon post flood response and mitigation of future losses. The second focused more specifically upon postflood response and the restoration of floodplain, wetland, and riparian areas.

The goals of the workshops were to assess post flood responses now taking place at all levels of government, to determine barriers to effective response, and to make recommendations for future actions for overcoming those barriers to the White House, federal agencies, Congress, the states and local governments, interest groups, and other interested parties.

The following are preliminary recommendations. They are based upon the workshop discussions, the summaries from the breakout sessions, questionnaires submitted to workshop attendees, and suggested recommendations sent to us. The preliminary recommendations will be sent to all attendees from the workshops for their review and comment before a final set of recommendations are prepared and distributed approximately October 20, 1993. We would, therefore, expect some changes.

Summary of Recommendations

We recommend that the White House, federal agencies, and Congress:

1. Provide real alternatives to floodplain occupants and local governments in their choice of options in responding to flood damage and reducing future damages by providing more flexibility in the use of disaster assistance funds and allocating additional funds, if necessary, to broaden the range of alternatives to include relocation "buy outs", structural floodproofing, creation of greenways, wetland restoration and other alternatives.

The alternatives offered in the recovery must be real. For these alternatives to be real the following conditions need to be satisfied.

- ♦ They must be timely so that those displaced have a clear vision of their future. Mid-recovery rule changes must be avoided especially when they increase the anxiety of the recovery victims.
- ♦ Priority items such as relocation of communities, and restoration of open space will be expensive and will exceed the resources currently funded to pursue these opportunities. Agencies should be given the flexibility to reprogram existing emergency funds towards these efforts.

More specifically we recommend:

- ♦ Amend P.L. 103-75 (107 Stat. 739) to provide the Federal Emergency Management Agency, the U.S. Corps of Engineers, the Department of Housing and Urban Development and the Soil Conservation

Service with more flexibility in the use of funds to provide landowners and local communities with real choices for post flood response for "buy outs", relocation, floodproofing and other nonstructural floodplain management where such alternatives would equal or reduce the long-term federal costs associated with structural flood loss reduction measures.

- ◆ Provide additional funds in any disaster supplemental bill (should one be adopted) for "buy outs", relocation, floodproofing, nonstructural alternatives, and technical assistance. A portion of this money might involve a reallocation of funds not presently being spent pursuant to 103-75. Particularly high priority programs would include the Corps's Section 99 (if more flexibility were available in use of funds) and 1135 programs, H.U.D.'s Community Block Grant Program, FEMA's Section 404 Mitigation Grant Program, SCS's Watershed and Wetland Reserve Program, the U.S. Fish and Wildlife Service's Partners for Wildlife Program, and the National Park Service's Rivers and Trails Program.
- ◆ Direct the USDA to examine and provide recommendations for a policy that evaluates swapping agricultural set aside lands from upland to floodplains. This policy while complex, warrants consideration since it provides a federal no cost alternative to farmers that economically need to produce a crop on flood prone land, but in the long-term may be able to shift or abandon that practice eliminating the need for flood control or agricultural disaster relief. Many farmers believe that upland farmers would be willing to exchange these credits since it may be economically attractive for them to farm the land than to accept the set aside payment.
- ◆ Direct the federal agencies to provide additional technical assistance with regard to the full "menu" of options for reducing future flood losses while, simultaneously, achieving a broad range of pollution control, recreation, economic alternatives for the Mississippi basin. We believe that SCS and the U.S. Fish and Wildlife Service should have the lead for rural, agricultural areas and FEMA, H.U.D., the Corps of Engineers, and the National Park Service, Rivers and Trails Program, should have the lead for urbanizing and urban areas.

2. Create a flood clearing-house and improve and tailor the delivery mechanisms for technical assistance, grant-in-aid, and other forms of assistance to the needs of various groups affected by flooding and more actively involve these groups in formulating and implementing long-term solutions.

More specifically, we suggest that:

- ◆ The federal agencies develop a package of information on all major federal grant-in-aid and technical assistance programs and distribute them widely to landowners and local governments,
- ◆ The federal agencies in cooperation with the states develop specific packages of information and technical assistance for the two major "communities" affected by flooding: (1) agricultural community, and (2) urban residents and local governments.
- ◆ The federal agencies in cooperation with the states provide community planning assistance to help communities develop and implement post disaster multi-objective river corridor plans. Strong citizen and interest group involvement is needed in the development of these plans.

3. Rapidly develop certain types of "priority" information and data critical to short and intermediate flood responses including more information concerning levees and wetland restoration sites.

More specifically, we suggest that:

- ◆ Federal agencies be directed to develop within 60 days preliminary information concerning all levees affected by this flood disaster including types, lengths, design standards, damage from flooding, types of structures and activities protected by the flooding, costs of repair, and possible impact on potential restoration sites. The Corps of Engineers should have the lead on this.
- ◆ Federal agencies be directed to develop within 60 days a preliminary inventory of "restoration" sites in the areas affected by the flood disaster including but not limited to potential sites for greenways and urban parks in urban areas, and wetland and riparian zone restoration sites. The U.S. Fish and Wildlife Service should have the lead on this.

4. Establish demonstration projects to show how processes can work and determine the effectiveness of various approaches.

More specifically, we recommend that demonstration projects be established including:

- ◆ At least five community planning sites involving "buy outs", relocation, urban renewal, or greenways in urban and urbanizing areas,
- ◆ At least five sites involving wetland restoration, riparian zone restoration, buy outs and other forms of restoration in rural areas.

- ◆ At least five sites involving integrated floodplain, wetland and watershed management.

5. Provide planning and technical assistance to states and communities.

The recovery options being discussed with this recovery are state and community intensive. To succeed, they will require strong, on the ground, planning and implementation. Small and medium communities specifically lack the planning resources to facilitate these efforts. This lack of resource is compounded by the fact that entire communities have fallen victim to the flood, so the community planners are having to deal from the difficult role of victim and visionary. Communities need planning and technical assistance support in helping shape their recovery plans. See recommendations 1-4, 6, and 7 which will all assist states and communities.

6. Treat flooding in the upper Mississippi basin as a prototype or "case study" to suggest possible future directions for multi-objective floodplain and watershed management and the restoration of aquatic ecosystems in other areas of the nation.

- ◆ Initiate a National Academy of Sciences Committee concerning flooding on the Mississippi, its causes, and long-term multi-objective management strategies.
- ◆ Request the Interagency Floodplain Management Task to make recommendations with regard to multi-objective floodplain and watershed management planning and restoration of the upper Mississippi.

7. Establish a "blue ribbon" commission as a first step in designating the upper Mississippi and its sub-basins as a special, multipurpose watershed planning, management, and restoration area with the goal of rebuilding communities (both human and natural).

More specifically, this commission and the resulting designation should serve as a national model for a new concept of infrastructure development with the goals of revitalizing towns and agricultural communities, creating jobs, and restoring natural ecosystems. Public works projects should be formulated with a geomorphic and hydrologic/ecosystem basis. The commission should include representatives appointed by the Governors, from cities and towns, from federal agencies, and from the scientific and design communities. The commission should report back to the White House and Congress within one year.

EXECUTIVE OFFICE OF THE PRESIDENT

Washington, D. C.

FAX TRANSMITTAL COVER SHEET

DATE: 19-Oct-93

TO: B. BURKE

SUBJECT:

OCTOBER 20TH FLOOD MEETING

FROM:

RENEE P. HELM (202) 395-4590

OFFICE OF MGMT AND BUDGET, NRD

If there are any problems receiving this transmission,
please call the sender, or (202) 395-7370.

October 19, 1993

NOTE TO: SEE DISTRIBUTION LIST

FROM: T.J. Glauthier and Katie McGinty

SUBJECT: Environmental Flood Recovery, Interagency Working Group

This is to remind you that we are planning a regular meeting of the Interagency Working Group for Wednesday, October 20th, at 10:00 am in room 248 of the Old Executive Office Building.

The agenda will consist of discussions of:

- * The latest version of the menu of Federal flood response alternatives to levees (copy distributed for final review October 15th).
- * The establishment of the "Scientific Assessment and Strategy Team" discussed previously by Mark Schaefer of the Office of Science and Technology Policy.
- * The comprehensive strategy paper.

DISTRIBUTION LIST:

Federal Agencies

Richard Krimm	FEMA
Larry Zensinger	FEMA
Bob Stearns	Army
Mollie Beattie	DOI-FWS
Michael Huerta	DOT
Richard Sanderson	EPA
David Davis	EPA-OW
Oleta Fitzgerald	USDA
James McMullen	USDA-ASCS
Karl Otte	USDA-SCS
Tom Wehri	USDA-SCS
Gene Morrison	HUD
Truman Goins	HUD
Kent Lim	DOC
Al Judd	SBA

Executive Office of the President

John Gibbons	OSTP
Mark Schaefer	OSTP
T.J. Glauthier	OMB-NRD
Katie McGinty	WH-OEP
Will Stelle	WH-OEP
Brian Burke	DPC
Kathi Way	~~OPB~~ DPC
Kevin Neyland	OMB

October 5, 1993

MEMORANDUM TO: T.J. GLAUTHIER
KATIE MCGINTY

THROUGH: Ron Cogswell Signed

FROM: Bruce D. Long Signed

SUBJECT: SCS Policy Guidance on Levee Reconstruction
and Wetland Reserve

Attached for your review is a restructured policy statement for SCS to issue to its field organizations regarding the above subject. This is the policy statement I discussed with you at the meeting last Friday morning. This restructure reflects comments received from internal Executive Office review as well as outside agencies including EPA, Army, and Interior.

The original, copy also attached, suffered from a number of flaws. It was poorly organized (unorganized some would say), the policies were either wrong (one would have permitted agency shopping), or simply inadequate to the issue it was supposed to address, and there were important omissions. Our rewrite is a fairly aggressive departure from their submission in a policy sense. However, they will still be able to recognize a considerable amount of the original text. There is still a lot of "fleshing out" required because our redraft simply provides the basic direction, not every word necessary for implementation in the field.

Following your review, I intend to meet with Karl to discuss our proposed changes. This must occur soon so that the policy can be promulgated.

If you have any questions or suggestion for further changes, please let me know.

Attachments

cc: Will Stelle
Brian Burke

REVISED BY OMB

PROPOSED OUTLINE FOR SCS GUIDANCE

I. PURPOSE

II. BACKGROUND

A. Jurisdiction

B. Cost Sharing -- make it clear that 75/25 is not negotiable

C. Consideration of alternatives to levee repair

III. POLICY FOR DETERMINING ELIGIBILITY FOR LEVEE REPAIR

IV. PRIORITIZATION (Recognition of limited funding)

V. WETLANDS RESERVE PROGRAM

[In both SCS and Corps jurisdictions, there should be an option to go into the wetlands reserve program whether or not they are declared eligible for repair under SCS or Corps program.]

[Note the current Section 5 indicates that if the Secretary determines that the cost of land and levee restoration exceeds the fair market value (post-flood, as if reclaimed) of an affected cropland, the Secretary may accept bids for the WRP. We need some sense of how often this could occur. Also, Section 5 is silent about agricultural lands protected by the Corps.]

VI. PROCESS

A. Coordination with other agencies through DFO

B. Timetable

I. PURPOSE:

Policies and procedures to determine jurisdiction, eligibility, and priorities for the repair of levees under the 1993 Emergency Supplemental Appropriations Act for Relief from the Major, Widespread Flooding in the Midwest.

II. BACKGROUND:

A. Jurisdiction

In 1986 the U.S. Department of Agriculture's Soil Conservation Service (SCS) and the U.S. Army Corps of Engineers (Corps) agreed in a Memorandum of Agreement (MOA), Appendix J, Emergency Watershed Program, National Watersheds Manual, to coordinate their activities as they relate to emergency assistance in the restoration of water control facilities damaged by flood. This included the many levees damaged by the recent Midwest flood. One of the areas of agreement in the MOA was that, as a general principle, the main stem levees (drainage areas greater than 400 square miles) would be the responsibility of the Corps. In the case of the current Midwest flood, this would include all of the main stem levees on the Upper Mississippi and Missouri Rivers and their major river tributaries. In a like manner, the small watersheds (drainage areas less than 400 square miles) up stream of the main stem levees would be the responsibility of SCS.

In implementing this MOA we have agreed with the Corps that we will not assist with the repair of main stem levees unless the levee is eligible for Corps repair and the Corps requests SCS to do so. Similarly, Corps may repair eligible non-main stem levees in response to an SCS request.

In implementing this MOA, we have determined that the coordination among relevant agencies should occur at the Disaster

Field Office (DFO). The Federal Emergency Management Agency (FEMA) levee coordinator will facilitate the review process at the DFO (see enclosed point of contact (POC) directory). All applications submitted will be reviewed by the POC at each agency. Any applications/requests submitted directly to the Corps will be submitted to the DFO for the interagency (IA) review process. Likewise, any applications received by SCS will also be shared with the IA DFO team.

B. Cost Sharing - Cost sharing required for repair of levees eligible for SCS assistance is 75/25. The 75/25 is not negotiable. [expand]

C. Consideration of alternatives to levee repair

It is important that the approach the levee review team uses to suggest a non-structural alternative is one that will not be misunderstood by the owner and will have the best chance of acceptance, particularly by the owner who has been denied Federal assistance to repair a levee. If a member of the levee review team believes that a levee repair project is a candidate for a non-structural alternative, the entire team should consider that matter prior to, or immediately after, the responsible agency conducts the initial inspection of the levee with the owner. The team leader, or his designee, should inquire about the owner's interest in an alternative at the earliest possible time, explaining the advantages of such an approach. Before contacting the owner, the relevant agency must be sure that the program it is suggesting is authorized and funded, where appropriate. With the full participation of the owner, the levee review team will examine whether the owner is an eligible applicant for the proposed alternative(s). The owner should be provided all relevant information and literature regarding the alternative(s), and the levee review team should make itself available for additional meetings with the owner if requested. The levee

review team must follow-up with the owner regarding alternatives and relevant information must be entered into the levee database. The levee review team members will continue to advise and assist landowners who wish to pursue construction, with the approval of the levee district or landowner, to allow for application and decision on non-structural alternatives.

III. POLICY FOR DETERMINATION OF ELIGIBILITY FOR LEVEE REPAIR

A. Levees will be eligible for repair when:

1. There is potential for loss of life without the repair.

2. The benefits associated with repairing the levee exceed the costs of levee repair and other levee-dependent costs -- cropland reclamation, facility repairs, and structure repairs -- that would occur only if the levee is rebuilt.

3. Owner agrees to meet Federal eligibility requirements for engineering and maintenance.

B. Levees will not be eligible for repair when the benefits associated with repairing the levee are less than the costs of levee repair and other levee dependent costs -- cropland reclamation, facility repairs, and structure repairs -- that will occur only if the levee is rebuilt.

C. Benefits and costs are measured with and without the levee repair. Since many of the damaged levees protect improvements (e.g., transportation facilities such as roads and railroad tracks, utilities, homes, commercial and industrial property, etc.) besides cropland, these improvements must be taken into consideration when determining whether or not to repair a damaged levee. Therefore, it is not possible to

determine if a specific levee will be repaired based solely on the cropland considerations.

1. Benefits include the damages to cropland, structures, and facilities (e.g., transportation facilities, utilities, homes, commercial and industrial property) that would be avoided with levee repair.

a. For cropland, benefits are the difference between the pre-flood fair market value of the land with the levee and the post-flood market value of land as if reclaimed, but without the levee. The value is estimated under the assumption that the levee cannot be rebuilt.

b. For structures and facilities whose repair is dependent on levee reconstruction, the measurement of benefits is the annual damages that would be avoided with the levee.

2. Costs.

(a) Cropland reclamation cost will include all individual, corporate, and governmental expenditures or values for the following items:

- (i) Cost to remove or replace material within a field.
- (ii) Cost of disposal or borrow areas.
- (iii) Cost to mix material in a field.
- (iv) Cost to repair field roads, stream crossings, fences, conservation practices, and any other farm infrastructure.

- (v) Cost to restore drainage and/or irrigation.
 - (vi) Cost to restore fertility including cost to remediate any toxic or hazardous materials found on the cropland.
 - (vii) Technical assistance.
- (b) Levee repair cost will include all individual, corporate, and governmental expenditures or values for the following items:
- (i) Cost of construction.
 - (ii) Cost of disposal or borrow areas.
 - (iii) Technical assistance.
 - (iv) Cost of future operation and maintenance.
- (c) Structure and facility costs include all individual, corporate, and governmental expenditures of repairing the structure. [new]
- (d) Environmental and wetlands.

The requirements of Part 509.32 of the National Watersheds Manual, the guidelines contained in the August 23, 1993, memorandum from OMB and the White House Office of Environmental Policy, and any applicable Federal, State, or local regulations will be followed. Wetland and cultural resource determinations for purpose of Endangered Species Act (ESA) will be made on all

tracts on which repair activities will take place. This determination will be made during the original field review of the site and will be considered before assistance is provided.

IV. PRIORITY RATING SYSTEM

Funds may not be available for all eligible levees. To establish the priority for determining assistance, each State shall have a priority ranking system based on 100 possible points.

Maximum of:

A. Risk of loss of life	50
B. Risk of loss of public facilities	10
C. Past performance of sponsor (including O&M)	10
D. Economic defensibility (B/C ratio or ratio of value of property to cost of repair)	10
E. Environmental impact (conform to all laws), highest score to lowest impact	10
F. Enforcement of local rules regarding use of flood plain	<u>10</u>
	100

V. WETLANDS RESERVE PROGRAM

The 1993 Emergency Supplemental Appropriations Act for Relief from the Major, Widespread Flooding in the Midwest Act states, "Provided further, that if the Secretary determines that the cost of land and levee restoration exceeds the fair market value of an affected cropland, the Secretary may use sufficient amounts from funds provided under this head to accept bids from willing sellers to enroll such cropland inundated by the Midwest floods of 1993 in any of the affected states in the Wetlands Reserve Program as authorized by Sub-chapter C of Chapter 1 of Subtitle D of Title XII of the Food Security Act of 1985 (16 U.S.C. 3837)." Page 6 of the Senate Committee on Appropriations Report on the Act states, "In addition, the request would allow the Secretary of Agriculture to accept bids from willing sellers to enroll cropland into the Wetlands Reserve Program if the cost of restoring the cropland and rebuilding levees exceeds the fair market value of the affected cropland." Fair market value for cropland to be used for comparison with pre-flood fair market value will be determined based on post-flood as if reclaimed conditions.

[Need to add something about eligibility of Corps Levees]

VI. PROCESS

A. Coordination

Disagreements among team members may arise concerning any aspect of levee repair coordination process. The DFO team should make every effort to resolve issues among themselves. If the team is unable to resolve differences, the FCO should mediate the issue. The FCO may consult with the Interagency Levee Rehabilitation

Task Force in Washington, D.C., before mediating the issue.

B. Timetables

1. Levee Repair

(a) All requests for assistance must be received by November 15, 1993.

(b) Damage survey reports which will include a wetland determination must be completed by November 30, 1993.

(c) Determine eligibility for repair by December 1, 1993.

(d) Priority listing for eligible sites must be completed by December 15, 1993.

DRAFT

Issue:

Policies and procedures to determine jurisdiction, eligibility and priorities for the repair of levees under the Emergency Supplemental Appropriations for Relief from the Major, Widespread Flooding in the Midwest Act of 1993.

Background:

In 1986 the Soil Conservation Service (SCS) and the United States Army Corps of Engineers (USACE) agreed in a Memorandum of Agreement (MOA), Appendix J, Emergency Watershed Program, National Watersheds Manual, to coordinate their activities as they relate to emergency assistance in the restoration of water control facilities damaged by flood. This included the several levees damaged by the recent Midwest flood. One of the areas of agreement in the MOA was that the main stem levees would be the responsibility of the USACE. In the case of the current Midwest flood this would include the Upper Mississippi River and its major river tributaries. In a like manner the small watersheds up stream of the main stem levees would be the responsibility of SCS.

In implementing this MOA we have agreed with the USACE that we will not assist with the repair of main stem levees unless the USACE or the local levee sponsors request SCS to do so, and then only after SCS consults with the USACE and becomes fully aware of

all the issues involving the levee. SCS will consult with and consider input from all of the Agencies on the State Disaster Field Office (DSO) levee team before making a decision. SCS will advise USACE and the DFO levee team of the compelling reasons for their decision to repair or not to repair a main stem levee. USACE will use a similar process for non-main stem levees that they may be asked to work on.

The Emergency Supplemental Appropriations for Relief from the Major, Widespread Flooding in the Midwest Act of 1993 states, "Provided further, that if the Secretary determines that the cost of land and levee restoration exceeds the fair market value of an affected cropland, the secretary may use sufficient amounts from funds provided under this head to accept bids from willing sellers to enroll such cropland inundated by the Midwest floods of 1993 in any of the affected states in the Wetlands Reserve Program as authorized by Sub-chapter C of Chapter 1 of Subtitle D of Title XII of the Food Security Act of 1985 (16 U.S.C. 3837)." Page 6 of the Senate Committee on Appropriations Report on the Act states, "In addition, the request would allow the Secretary of Agriculture to accept bids from willing sellers to enroll cropland into the Wetlands Reserve Program if the cost of restoring the cropland and rebuilding levees exceeds the fair market value of the affected cropland".

It is important that the approach the levee review team uses to suggest non-structural alternatives is one that will not be misunderstood by the owner and will have the best chance of acceptance, particularly by the owner who has been denied Federal assistance to repair a levee. If a member of the levee review team believes that a levee repair project is a candidate for a non-structural alternative, the entire team should consider that matter prior to, or immediately after, the responsible agency conducts the initial inspection of the levee with the owner. The team leader, or his designee, should inquire about the owner's interest in an alternative at the earliest possible time, explaining the advantages of such an approach. Before contacting the owner, the relevant agency must be sure that the program it is suggesting is authorized and funded, where appropriate. With the full participation of the owner, the levee review team will examine whether the owner is an eligible applicant for the proposed alternative(s). The owner should be provided all relevant information and literature regarding the alternative(s) and the levee review team should make itself available for additional meetings with the owner if requested. The levee review team must follow-up with the owner regarding alternatives and relevant information must be entered into the levee database. The levee review team members will continue to advise and assist landowners who wish to pursue construction, with the approval of

the levee district or landowner, to allow for application and decision on non-structural alternatives.

Disputes among team members may arise concerning any aspect of levee repair coordination process. The DFO team should make every effort to resolve disputes among themselves. If the team is unable to resolve differences, the FCO should mediate the issue. The FCO may consult with the Interagency Levee Rehabilitation Task Force in Washington before mediating the issue.

Since many of the damaged levees protect improvements, such as transportation facilities, utilities, homes, commercial and industrial property, etc., besides cropland, these improvements must be taken into consideration when determining whether or not to repair a damaged levee. Therefore, it is not possible to determine if a specific levee will be repaired based solely on the most cost-effective approach for the reclamation and further protection of cropland.

Recommended Policies:

1. Levees will be eligible for repair when:
 - A. There is a potential for loss of life.
 - B. The potential damage to improvements other

than cropland, such as transportation facilities, utilities, homes, commercial and industrial property, exceeds the cost of levee repair.

C. The potential damage to improvements other than cropland and the fair market value of the cropland which does not need reclamation exceeds the cost of levee repair.

2. Levees will not be eligible for repair when the cost of the levee repair and the cost of cropland reclamation exceeds the fair market value of all cropland and the potential damages to other improvements such as transportation, facilities, utilities, homes, commercial and industrial properties unless there is a danger of loss of life.

3. Fair market value for cropland to be used for comparison with reclamation cost will be determined based on post-flood as if reclaimed conditions.

4. Cropland reclamation cost will include all individual, corporate, and governmental expenditures or values for the following items:

- A. Cost to remove or replace material within a field.
- B. Cost of disposal or borrow areas.

- C. Cost to mix material in a field.
 - D. Cost to repair field roads, stream crossings, fences, conservation practices, and any other farm infrastructure.
 - E. Cost to restore drainage facilities.
 - F. Cost to restore fertility.
 - G. Technical assistance.
5. Levee repair cost will include all individual, corporate, and governmental expenditures or values for the following items:
- A. Cost of construction.
 - B. Cost of disposal or borrow areas.
 - C. Technical assistance.
6. Environmental and wetlands.

The requirements of Part 509.32 of the National Watersheds Manual, the guidelines contained in the August 23, 1993, memorandum from OMB and the White House Office of Environmental Policy, and any applicable federal, state, or local regulations will be followed. This is to include 404 and FSA requirements. Wetland and cultural resource determinations will be made on all tracts on which construction will take place. This

determination will be made during the original field review of the site and will be considered before assistance is provided.

7. Priority Rating System

To establish the priority for determining assistance each state shall have a priority ranking system.

Suggested evaluation elements are:

- A. Risk to life or property ----- 50
 - 1. Loss of Life ----- 50
 - 2. Property only ----- 10

- B. Past Performance of Sponsors ----- 10
 - 1. Fulfilled all local responsibilities
in a timely manner or have not
sponsored past project ----- 10
 - 2. Fulfilled most local
responsibilities in a timely manner ---- 5
 - 3. Did not fulfill some local
responsibilities ----- 0

- C. Past record of sponsors' O&M ----- 10
1. Have taken advantage of past
programs ----- 10
 2. Have performed normal O&M ----- 5
 3. Have not performed O&M ----- 0
- D. Economic defensibility ----- 10
1. Value of property at risk is equal to
or greater than ten times the cost of
repair ----- 10
 2. Value of property at risk is equal
to or greater than five times the cost
of repair ----- 5
 3. Value of property at risk is equal to or
greater than the cost of repair ----- 1
- E. Environmental impact ----- 10
1. None ----- 10
 2. Slight ----- 7
 3. Moderate ----- 3
 4. Major ----- 0
- F. Local rules and regulations ----- 10
1. In place, good enforcement ----- 10
 2. In place, lax enforcement ----- 5
 3. None in place ----- 0

Total possible ----- 100

8. Timetables

A. Levee Repair

- (1) All requests for assistance must be received by November 15, 1993.
- (2) Damage survey reports which will include a wetland determination must be completed by November 30, 1993.
- (3) Determine eligibility for repair by December 1, 1993.
- (4) Priority listing for eligible sites must be Completed by December 15, 1993.

**OFFICE OF MANAGEMENT AND BUDGET
WATER RESOURCES BRANCH**

Telecopier Cover Sheet

Fax Number 202-395-4652 / Office Number 202-395-4590

*** PLEASE VERIFY RECEIPT ***

Date: 10/1

Please deliver the following pages to:

NAME: TJ Glavin
Will Stelke
Brian Burke **FAX #:** _____

AGENCY: _____

FROM: Bruce Lay

Number of pages to follow: 3

ADDITIONAL MESSAGES:

FYT, Corps' directing to field to
try to get habitat restoration projects
identified.



DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF:

28 SEP 1993

CECW-PM

MEMORANDUM FOR

COMMANDER, LOWER MISSISSIPPI VALLEY DIVISION
COMMANDER, MISSOURI RIVER DIVISION
COMMANDER, NORTH CENTRAL DIVISION

SUBJECT: Identification of Potential Section 1135 Projects
Within the Midwest Flood Area

1. Reference Memorandum, CECW-OE-D, dated, 20 August 1993, subject: "Levee Rehabilitation Program - 1993 Midwest Floods," paragraph 4.
2. There is considerable interest in incorporating habitat restoration in the post-flood recovery activities in the Midwest. The U.S. Army Corps of Engineers can take an active role by using this opportunity to identify potential environmental modifications of those levees constructed by the Corps requiring repair as a result of the flood and instituting expedited procedures to initiate section 1135 feasibility phase studies. I would like each of you to give this your personal attention. Success will require close cooperation among our staffs, the potential non-Federal sponsors and the resource agencies.
3. As an initial step I want each of you to review the Corps levees requiring repair to identify potential section 1135 projects. Modifications would not be limited to the immediate vicinity of the necessary repairs but must involve modification of the levee being repaired. Examples of the types of projects which may be considered are gated control structures to control water levels in areas which were previously wetlands, opening oxbows cut off by the levees and navigation projects, or perhaps realignment of levees to allow areas between the levees and the channel to revert to historic floodplain habitat. The goal remains restoration of previously existing habitat. An abbreviated fact sheet containing the information indicated in the enclosure should be prepared for each potential candidate and forwarded to CECW-PM by 15 October 1993. Additionally, each Major Subordinate Command (MSC) should identify a point of contact for coordination of the field visits.
4. A task force comprised of members of my staff will review the fact sheets and arrange for field visits to each of the potential project locations. The task force will be authorized to approve initiation of feasibility phase studies, on site, after a field briefing. In addition to appropriate members of

Abbreviated Fact Sheet

1. Name of Project being modified
2. Location - River mile nearest city/county
3. Congressional Dist. / State Corps District
4. Name of the potential non-Federal sponsor
5. A sentence describing what is being protected
6. Required repair - location, extent, cost, timing
(a few words to briefly explain the above and supplement a drawing)
7. Potential 1135 mod. - Nature, location relative to the repair, extent, cost, timing - indicate if there is any potential to integrate the repair and the modification
8. A sentence or two describing the potential habitat changes which would be achieved: such as reopening a blocked oxbow, creating a wetland of approx. ten acres, providing spawning areas.
9. Rough idea of lands required/ current ownership - Fed/State/or private
10. Potential non-Federal sponsor - including any preliminary expressions of interest in the concept.
11. Funds required for the report in the current FY
Total estimated report cost
12. Drawing (may be freehand) showing relation of the proposed modification and required lands in relation to the project being modified and the repair required due to flooding.

CECW-PM
SUBJECT: Identification of Potential Section 1135 Projects
Within the Midwest Flood Area

your staff, attendees at the field briefings should include representatives of the potential sponsor, state fish and wildlife agency and the U.S. Fish and Wildlife Service. Letters of intent from potential sponsors will be required within 45 days of initiation of the studies, and the final reports will be expected within 6 months of study initiation. If necessary, you should consider requesting staffing assistance from other MSC's, in order to meet these ambitious schedules. Any issues which may affect completion of the study or approval of the recommended plan should be brought to my attention at the earliest possible stage to eliminate delays during report review.

5. If you have any questions regarding this memorandum, my point of contact is Ms. Ellen Cummings, CECW-PM at (202)272-8532.

Encl


STANLEY G. GENEGA
Major General, USA
Director of Civil Works

CF:

COMMANDER (w/encl):
COMMANDER, NORTH ATLANTIC DIVISION
COMMANDER, NEW ENGLAND DIVISION
COMMANDER, NORTH PACIFIC DIVISION
COMMANDER, OHIO RIVER DIVISION
COMMANDER, PACIFIC OCEAN DIVISION
COMMANDER, SOUTH ATLANTIC DIVISION
COMMANDER, SOUTH PACIFIC DIVISION
COMMANDER, SOUTHWESTERN DIVISION

October 7, 1993

Note to: Mark Schaeffer
Bob Stearns
Karl Otte
Will Stelle
Brian Burke
Michelle Altemus
Richard Sanderson
Ron Cogswell
Kevin Neyland

From:  Bruce Long

Attached is a draft study prepared for the Illinois Department of Conservation. It purports to establish the relationship between wetlands and streamflows. I am not qualified to pass on the validity of its conclusions, but believe that you should have the benefit of their thinking on this subject.

The study addresses a key technical issue in our thinking about future responses to flooding: whether a certain amount of wetlands can be reliably and economically substituted for levees and other flood control works.

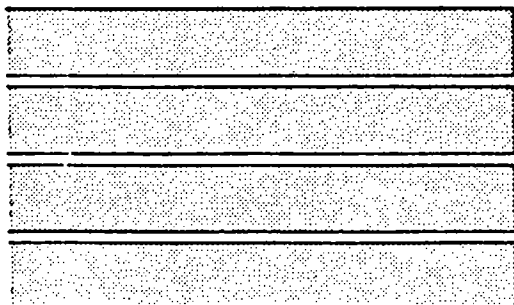
DRAFT

Influence of Wetlands on Streamflow in Illinois

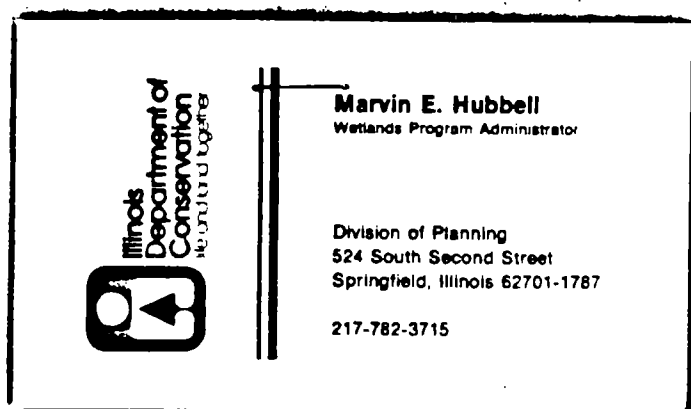
by Misganaw Demissie and Abdul Khan
Office of Sediment & Wetland Studies

Prepared for the
Illinois Department of Conservation

August 1993



Illinois State Water Survey
Hydrology Division
Champaign, Illinois



A Division of the Illinois Department of Energy and Natural Resources

DRAFT

INFLUENCE OF WETLANDS ON STREAMFLOW IN ILLINOIS

By
Misganaw Demissie and Abdul Khan

Prepared for the
Illinois Department of Conservation

Illinois State Water Survey
2204 Griffith Drive
Champaign, Illinois 61820-7495

August 1993

CONTENTS

	Page
Acknowledgments	ii
Tables	iii
Figures	iv
Abstract	vi
Introduction	1
Review of Literature	4
Data Analysis Methodology and Study Site Selection	7
Selection of Watersheds and Gaging Stations	7
Methods and Procedures	7
Flow Synthesis	7
Peakflow and Floodflow Volume	12
Low Flow	17
Evaluation Procedure	17
Testing Method	20
Results	23
Peakflow and Floodflow Volume	23
Statewide Analysis	23
Regional Analysis	28
Seasonal Analysis	30
Seasonal-Regional	38
Fall	38
Winter	39
Spring	39
Summer	40
Low Flow	41
Statewide Analysis	41
Regional Analysis	41
Seasonal Analysis	41
Seasonal-Regional	46
Fall	46
Winter	46
Spring	46
Summer	48
Summary and Conclusions	49
References	52

ACKNOWLEDGMENTS

This study was accomplished as part of the regular work of the Illinois State Water Survey. The research upon which this report is based was supported in part by funds provided by the Illinois Department of Conservation (IDOC). Marvin Hubbell was the project manger for IDOC and provided valuable guidance and coordination for the project. Radwan Al-Weshah, graduate research assistant at the Water Survey and Venkat Swaminathan and Charles Kemper, students at the University of Illinois, were helpful in processing the data and preparing many of the illustrations. Becky Howard typed the camera-ready copy of the report, Gail Taylor and Eva Kingston edited it, and Linda Hascall and David Cox prepared some of the illustrations.

TABLES

Page

1	Information on Streamflow Gaging Stations Used in the Study.....	
2	Regression Analysis Results and Percent Change for Statewide Analysis	
3	Regional Regression Coefficients and Percent Change Values for Peakflow and Floodflow Parameters.....	
4	Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Average Precipitation Ratio (Q_p/P_a) for a One Percent Change in Wetland Area	
5	Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Peak Precipitation (Q_p/P_a) for a One Percent Change in Wetland Area	
6	Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Total Precipitation (Q_p/P_t) for a One Percent Change in Wetland Area	
7	Influence of Wetlands on Floodflow Volume as Measured by the Percent Change in the Ratio of Floodflow Volume to Total Precipitation (V/P_t) for a One Percent Change in Wetland Area	
8	Regional Variability of Influence of Wetlands on Low Flow in Illinois as Measured by the Percent Change in Q_{95} and Q_{99}	
9	Seasonal Variability of Influence of Wetlands on Low Flow in Illinois as Measured by the Percent Change in Q_{95} and Q_{99}	
10	Seasonal Variability of Influence of Wetlands on Low Flow by Region in Illinois as Measured by the Percent Change in Q_{95} and Q_{99}	

FIGURES

Page

1	Locations of selected drainage basins, streamgaging stations, and precipitation stations.....
2	Frequency distribution of drainage areas of selected watersheds
3	Frequency distribution of wetland percentages in selected watersheds
4	Frequency distribution of storm values of peakflow to average precipitation ratio for three selected stations.....
5	Frequency distribution of storm values of peakflow to peak precipitation ratio for three selected stations.....
6	Frequency distribution of storm values of peakflow to total precipitation ratio for three selected stations.....
7	Frequency distribution of storm values of floodflow volume to total precipitation ratio for three selected stations.....
8	Determination of flows at different exceedance probabilities.....
9	Percent change (PC) determination from regression parameters
10	Relation between peakflow to average precipitation ratio and percent wetland for Illinois
11	Relation between peakflow to peak precipitation ratio and percent wetland for Illinois
12	Relation between peakflow to total precipitation ratio and percent wetland for Illinois
13	Relation between floodflow volume to total precipitation ratio and percent wetland for Illinois
14	Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland
15	Seasonal variation of the relations between peakflow and floodflow volume parameters and percent wetland

FIGURES (concluded)

- 16 Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for fall
- 17 Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for winter
- 18 Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for spring
- 19 Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for summer
- 20 Relation between low-flow parameter, Q_{95} , and percent wetland for Illinois
- 21 Relation between low-flow parameter, Q_{99} , and percent wetland for Illinois
- 22 Seasonal variation of the relation between parameters Q_{95} and Q_{99} and percent wetland low flow

ABSTRACT

One of the major functions of wetlands is to store water and release it gradually to surface and ground-water bodies. It is generally assumed that wetlands reduce flooding, increase low flows, and serve as recharge areas for ground water. However, there have not been systematic studies to quantify the influence of wetlands on flooding and low flows. This research was initiated to investigate the hydrologic functions of wetlands in Illinois based on available streamflow records. The research was designed to answer the more general question, "how does the presence or absence of variable size wetlands in a watershed influence streamflow?"

Streamflow records from 30 gaging stations monitoring watersheds with variable wetland areas were analyzed to assess the influence of wetlands on streamflow. The main objective of the analysis was to determine if streamflow parameters of streams draining watersheds with varying percentage of wetland areas were related to the percentage of wetlands in the watersheds. The streamflow parameters analyzed included peakflow, floodflow volume, and low flow. From the results of this analysis, in general, it can be concluded that peakflow and floodflow volume decrease, and low flows increase with increasing percentage of wetlands in the watershed. The influence of wetlands was more noticeable on peakflow and low flow than on floodflow volume. For all the gaging stations analyzed, the peakflow to average precipitation ratio decreased on the average by 3.7 percent, floodflow volume to total precipitation ratio decreased by 1.4 percent, and low flow (represented by Q₉₅) increased by 7.9 percent for an increase of one percent wetland area in a watershed. There were, however, significant regional and seasonal differences in the rate of change.

Regionally, wetland influence was more noticeable in central and northern Illinois than in southern Illinois for both peakflow and floodflow volume. The influence of wetlands on low flow was more noticeable in southern and northern Illinois than in central Illinois, however. The peakflow to average precipitation ratio decreased by 5.9 to 7.9

percent, while floodflow volume to total precipitation ratio decreased by 4.5 and 2.3 percent in central and northern Illinois, respectively. For low flow, Q95 increased by 15.9 and 15.0 percent in southern and northern Illinois, respectively.

Seasonally, for the state as a whole, wetland influence was the most prominent in fall for the peakflow to average precipitation ratio (5.7 percent decrease) and in summer for the floodflow volume to total precipitation ratio (3.1 percent decrease). For low flow, the influence of wetlands was equally noticeable in fall (8.4 percent increase in Q95) and summer (8.0 percent increase in Q95).

INFLUENCE OF WETLANDS ON STREAMFLOW IN ILLINOIS

by
Misganaw Demissie and Abdul Khan
Office of Sediment & Wetland Studies
Illinois State Water Survey
Champaign, Illinois

INTRODUCTION

The objective of this project was to assess the influence of wetland acreage on streamflow by analyzing existing streamflow records in Illinois. Analysis of streamflow records for streams with various ratios of wetlands in their watersheds may provide information on how wetlands influence the hydrology of the watershed. If streams draining watersheds with different percentages of wetland area to total drainage area have different hydrologic responses, then general relationships can be developed between percentages of wetland and streamflow parameters. These relationships can then be used to evaluate wetland functions and impacts of land-use practices that affect wetland acreage.

There are four major mechanisms by which wetlands can influence streamflows: runoff generation, flow retardation due to increased flow resistance, storage, and low-flow augmentation. Runoff generation is linked to wetlands' soil moisture and land-cover conditions, important parameters that greatly influence how much runoff is generated from various rainfall events. For example, if an area is already saturated from antecedent rainfall, even small precipitation amounts can produce large surface runoff. On the other hand, if an area is dry, large precipitation amounts may produce little or no runoff as most of the precipitation infiltrates into the ground. An area with dense vegetation will intercept more incoming rainwater than an area with little or no vegetative cover. As a result, surface runoff from the former will be much less than that from the latter. In

contrast, delayed flow from an area with dense vegetation will be greater than from an area with less vegetative cover.

The presence of wetland vegetation in the watershed and along drainage channels will increase flow resistance over land and in the streamchannels resulting in slow delivery of runoff from upstream to the streamchannel. When a flood event occurs along a stream in a watershed with wetlands along the streambanks, the streamflow increases and eventually overflows the banks. The water then has to flow through the adjoining wetlands, which significantly increases the resistance to flow. Since wetlands typically support a large amount of vegetation, the resistance to overbank flow is greater for a stream adjoining a wetland than for a stream not adjoining a wetland. As a result, a significant difference will exist between the flow characteristics of a stream adjacent to a wetland and one not adjoining a wetland.

Another major influence that wetlands exert on streamflow is the flood storage capacity they provide. Since most wetlands are located in depressions and poorly drained areas, they provide significant storage potential. By storing runoff from adjoining areas, wetlands retard or reduce the amount of runoff that reaches streamchannels. Therefore depending on initial conditions, wetland areas could significantly affect the streamflow.

The presence of wetlands in a watershed may also result in low-flow augmentation in streams. In wetland areas, water stored in surficial depressions and underground is gradually released to adjoining streams during periods of low flows. This generally results in higher low-flow conditions for streams that drain areas containing wetlands.

One of the parameters that can be used to characterize and distinguish watersheds containing different areas of wetlands is the ratio of wetland area to the total drainage area of the watershed. The major objective of this study, therefore, was to investigate streamflow records in Illinois and relate various streamflow parameters to the percentage of wetlands in the watershed. Although it is generally accepted that wetlands reduce streamflow peaks and increase low flows, this generalized concept may not always be true.

The hydrologic response of wetlands may vary depending on geographic location, storm intensity and duration, and season of the year. Because of significant regional and seasonal differences in Illinois, it is important to ascertain if the influence of wetlands varies between regions and by season. This research effort has attempted to address issues related to the regional and seasonal influence of wetlands on streamflow in Illinois. However, because of the small number of stations in the different regions, the regional analysis needs to include more stations in the analysis.

REVIEW OF LITERATURE

The role of wetlands on streamflow has been a subject of considerable debate. Past studies have served only to highlight this debate and the differing conclusions. Irwin and Whiteley (1983), Bardecki (1987), and Brunner (1988) have reviewed results from previous studies related to the influence of wetlands on streamflow.

McCubbin (1938) concluded that drainage activity did not have any impact on the peakflow values of the Grand River or the Thames River in Ontario, Canada. O'Kelly (1955), while investigating the influence of artificial drainage on flood hydrographs, found that the peakflow increased substantially after drainage. Prior and Hess (1961) performed flood frequency analysis for Minnesota and decided that flood magnitude was reduced with increasing percentage of marshes in the watershed. They assumed that a percentage of lakes represented the percentage of marshes in the watershed.

In a series of studies, Haan and Johnson (1968), DeBoer and Johnson (1969), and Campbell and Johnson (1975) used the Iowa State Model to examine the influence of wetland drainage on streamflow by using storm hydrograph simulations. They concluded that drainage usually increased the runoff volume irrespective of the rainfall intensity and duration. For high-intensity, short-duration rainfall, the peakflow values remain unchanged even with improved drainage, while for low-intensity, long-duration events, peakflows in general increased with increased drainage. Moore and Larson (1979), using an improved version of the Iowa State Model, called the Minnesota Model, reached essentially similar conclusions.

Burke (1968), in an investigation of two watersheds, one drained and the other undrained, found that peakflow was lower in the drained watershed than in the undrained watershed. Kloet (1971), in a similar study, reached exactly the opposite conclusion. McGill and Bennet (1971) studied the effect of drainage on runoff using a synthetic

hydrograph approach and concluded that drainage resulted in an insignificant reduction in peak discharge value.

Moklyak et al. (1972) investigated a drained and an undrained watershed, and concluded that drainage decreased both annual runoff and peakflow. Eggelsmann (1972) investigated two adjoining high water table peat watersheds, one undrained and the other drained by a tile drainage system. He found that while the runoff volumes from the two watersheds were similar, peakflows from the undrained peat basin were much greater (up to three times) after a rainfall event than those from the tile-drained watershed. Bailey and Bree (1980), in a study of 12 boggy watersheds, found that flood peaks were substantially increased as a result of drainage. Novitzki (1982) studied the influence of wetlands on streamflow in Wisconsin and concluded that flood peaks may be as much as 80 percent lower in basins with much lake and wetland area. Eli and Rauch (1982), in a study of two wetland watersheds in northern West Virginia, concluded that wetlands had little effect on peakflows or low flows of the studied watersheds. Skaggs and Broadhead (1982) studied the impact of drainage on runoff volume and peakflow using the model DRAINMOD. They concluded that subsurface tile drainage decreased the runoff volume and peakflow values.

Ogawa and Male (1983) studied the role of wetlands on streamflow in Massachusetts and found that peakflow increased with decreasing wetland percentage in the watershed. Demissie et al. (1983) studied the upper Kankakee and Iroquois Rivers in Illinois and Indiana. Significant wetlands were present along the upper Kankakee River and absent along the Iroquois River. They found that 50-year flood in the Iroquois River was almost twice of that in the upper Kankakee River for the same drainage area. On the other hand, the 7-day, 10-year low flow for the upper Kankakee River was more than ten times of that in the Iroquois River for the same drainage area.

It was mentioned previously that it is generally accepted that wetlands reduce streamflow peaks and increase low flows. This function of wetlands is attributed to their

ability to store floodwater during storm events for release later. However, this generalized concept may not always be true as illuminated by the review of literature of work done by researchers in the past. Depending on the extent of the wetland, its geographic location, storm intensities and durations, and seasons of the year, the influence of wetlands on streamflow may vary greatly with the region as well as the specific wetland type. As a result, it is imperative that these factors be given careful consideration when investigating the influence of wetlands on streamflow.

DATA ANALYSIS METHODOLOGY AND STUDY SITE SELECTION

In this section, the basis of selecting the watersheds and streamgaging stations for analysis will be outlined. The methods and procedures used will also be described.

Selection of Watersheds and Gaging Stations

Before analyzing streamflow records, it was necessary to exclude streams and watersheds that are significantly affected by known natural or man-made features. For example, streams greatly influenced by large rivers and lakes like the Mississippi and Ohio Rivers and Lake Michigan were excluded from analysis. All gaging stations located downstream of dams and major discharge points were also excluded. After considering these factors, 30 gaging stations were selected: 11 in southern Illinois, 8 in central Illinois, and 11 in northern Illinois. Table 1 lists the selected watersheds and the gaging stations, and figure 1 shows their locations. The drainage areas of the selected stations ranged from 7 to 1,282 square miles. The percentages of wetlands in these watersheds varied from a minimum of 0.2 percent to a maximum of 13.7 percent. The streamflow data for these watersheds were available for periods of at least ten years from 1979 to 1988. The frequency distributions of the watershed drainage areas and wetland percentages are provided in figures 2 and 3, respectively.

Methods and Procedures

Flow Synthesis

The analysis was conducted for a ten-year period from 1979 to 1988. This period was selected to closely correspond to the wetland area data that were determined from the National Wetland Inventory conducted in the early 1980s. Daily flow values for the ten-year period were obtained for each of the gaging stations. Three streamflow parameters were selected for analysis: peakflow, floodflow volume, and low flow. Daily precipitation

Table 1. Information on Streamflow Gaging Stations Used in the Study

<i>Streamflow station</i>	<i>ID number</i>	<i>Stream name</i>	<i>Drainage area (sq mi)</i>	<i>Wetland (percent)</i>	<i>Period of record</i>
03336645	1	Middle Fork Vermilion	428.00	1.34	1979-1988
03336900	2	Salt Fork River	131.10	0.22	1960-1988
03379500	3	Little Wabash	1118.90	1.06	1915-1988
03380500	4	Skillet Fork	457.83	4.04	1929-1988
03382100	5	South Fork Saline	145.10	9.29	1966-1988
03384450	6	Lusk Creek	42.40	0.47	1969-1988
05466500	7	Edwards River	440.30	1.08	1935-1988
05469000	8	Henderson Creek	430.30	0.82	1935-1988
05495500	9	Bear Creek	345.20	1.87	1944-1988
05532000	10	Addison Creek	22.90	0.76	1952-1988
05534500	11	North Branch Chicago	19.50	4.41	1953-1988
05536000	12	North Branch Chicago	98.10	3.52	1951-1988
05536275	13	Thorn Creek	102.90	8.64	1947-1988
05539900	14	West Branch DuPage	27.90	6.06	1961-1988
05540095	15	West Branch DuPage	92.30	7.53	1969-1988
05550500	16	Poplar Creek	35.50	7.28	1952-1988
05551700	17	Blackberry Creek	69.60	4.19	1961-1988
05568800	18	Indian Creek	62.20	0.47	1960-1988
05570370	19	Big Creek	40.70	8.43	1972-1988
05570380	20	Slug Run	7.10	13.68	1975-1988
05570910	21	Sangamon	237.70	0.80	1979-1988
05585000	22	La Moine	1281.80	2.27	1921-1988
05591200	23	Kaskaskia	468.90	0.87	1971-1988
05593520	24	Crooked Creek	251.60	5.80	1975-1988
05594450	25	Silver Creek	152.49	4.17	1967-1988
05594800	26	Silver Creek	460.75	5.64	1971-1988
05595200	27	Richland Creek	127.12	2.65	1970-1988
05595730	28	Rayse Creek	90.40	4.23	1979-1988
05597000	29	Big Muddy River	783.60	11.78	1915-1988
05597500	30	Crab Orchard	31.30	8.09	1952-1988

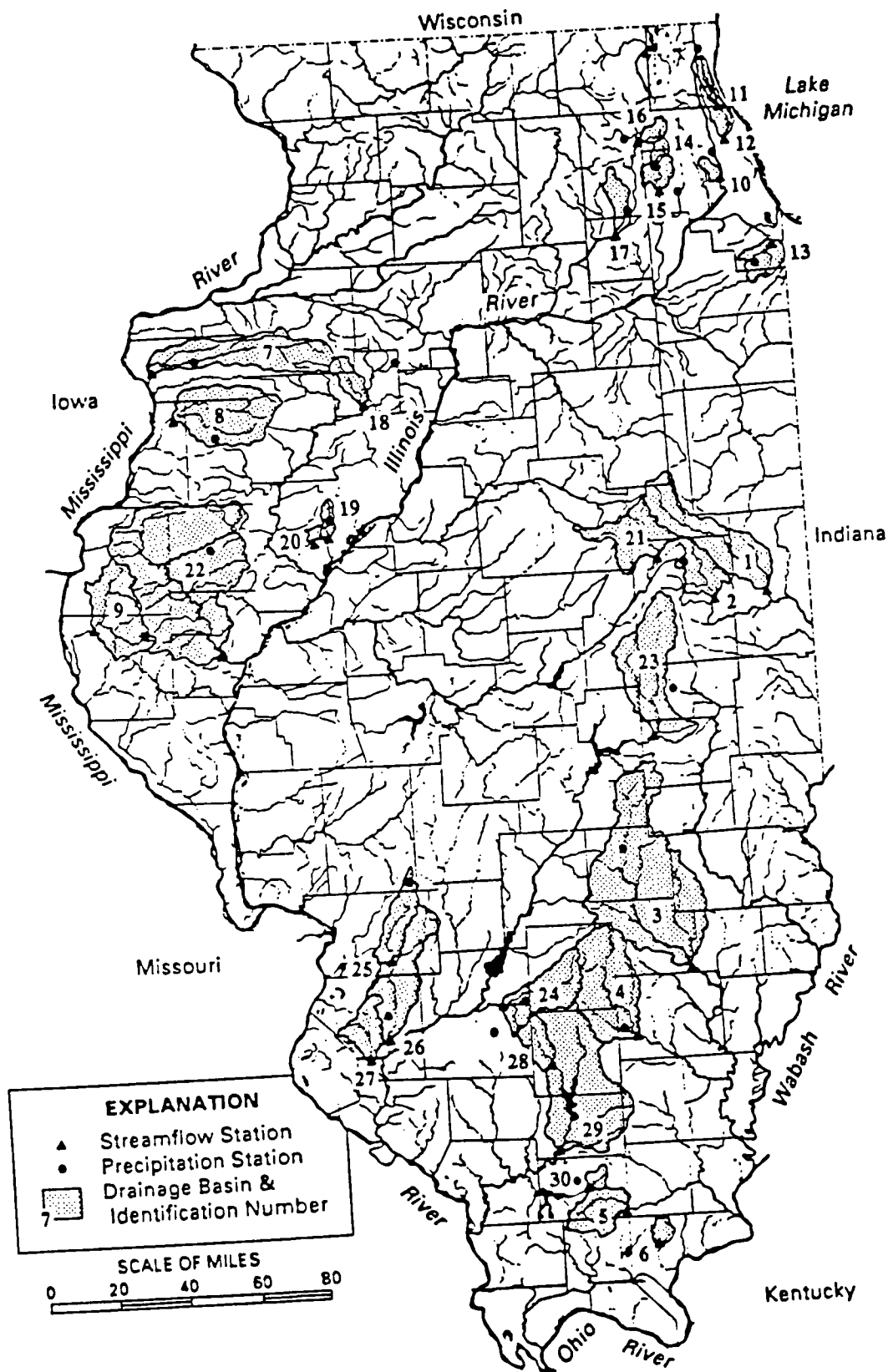


Figure 1. Locations of selected drainage basins, streamgaging stations, and precipitation stations

NUMBER OF WATERSHEDS

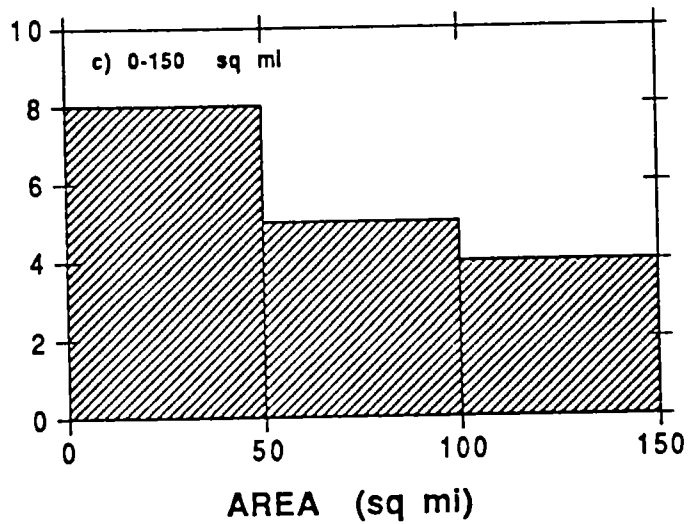
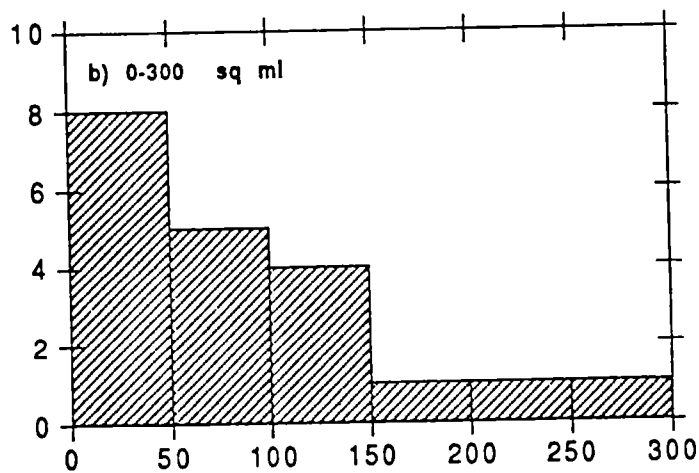
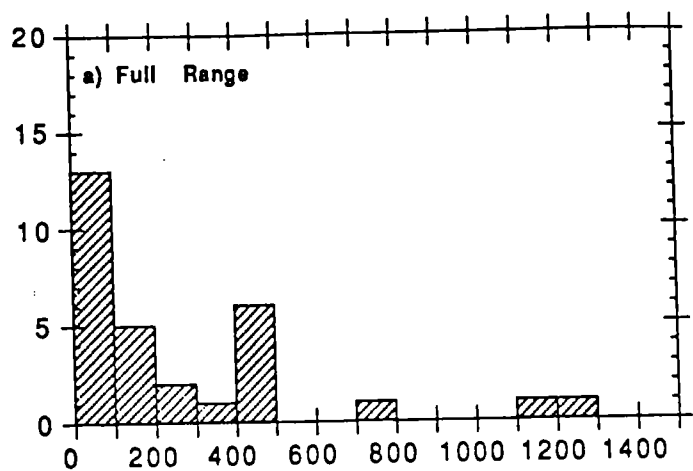
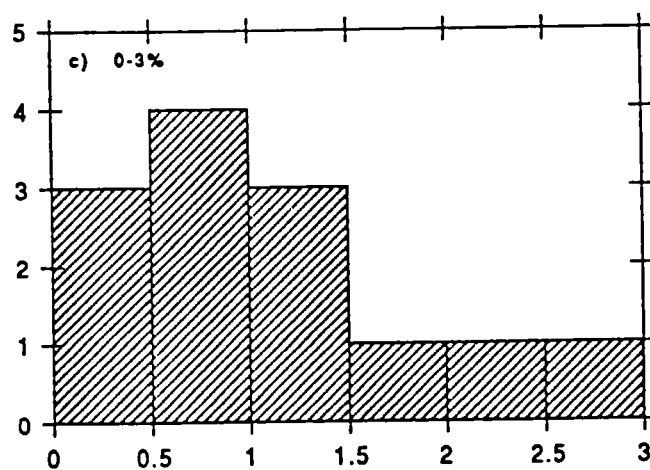
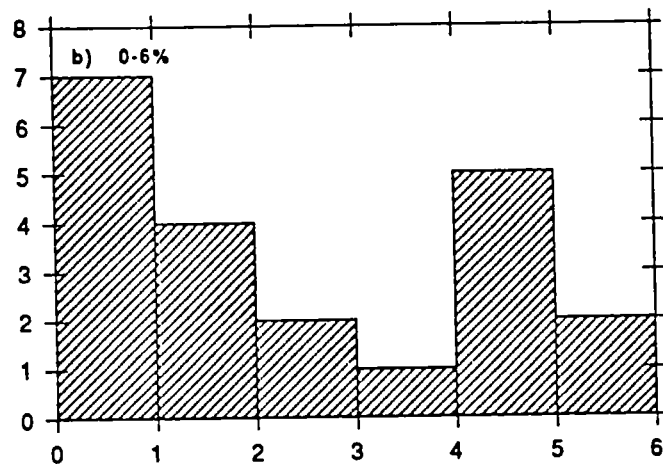
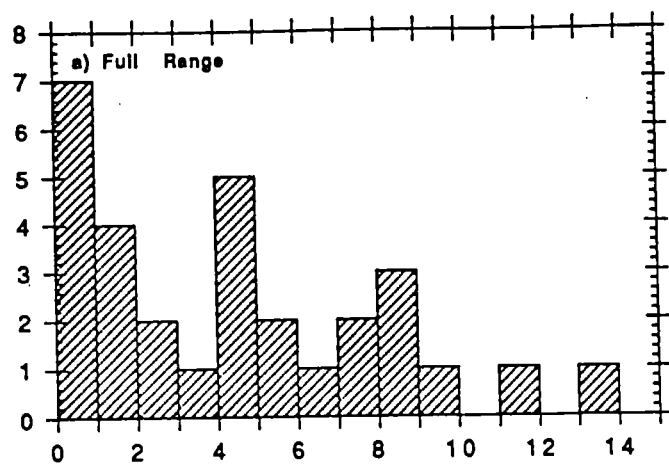


Figure 2. Frequency distribution of drainage areas of selected watersheds

NUMBER OF WATERSHEDS



PERCENT WETLAND

Figure 3. Frequency distribution of wetland percentages in selected watersheds

data from a station in the watershed for the same period were also obtained to normalize the streamflow.

Peakflow and Floodflow Volume. For peakflow and floodflow volume analyses, daily streamflow data for each year were examined and several flood events were selected. The peakflow values in cubic feet per second (cfs) were divided by drainage area and converted to inches per day. The corresponding volumes of the flood were also computed, and the seasons in which the floods occurred were identified. From the daily precipitation data, the average, peak, and total precipitation values associated with the selected flood events were determined. In order to remove the influence of the variability in precipitation from the analysis, four ratios were then calculated for each flood event to aid in the analysis: peakflow to average precipitation ratio; peakflow to peak precipitation ratio; peakflow to total precipitation ratio; and floodflow volume to total precipitation ratio.

For each station, the mean value for each normalized parameter was computed from the data for all the flood events. The frequency distribution of the individual values (used to compute the mean values) of the four parameters for Skillet Fork, Big Creek, and Crooked Creek are shown in figures 4-7. The distributions for the other stations were similar. The mean normalized parameters so computed were plotted against the corresponding percentages of wetlands for the watershed. The independent variable was the percentage of wetlands within each watershed. These values were generated by the Illinois Natural History Survey from the Illinois component of the National Wetland Inventory.

To investigate the regional influence on the peakflow and volume ratios, the mean normalized parameters were plotted by grouping the watersheds into three regions: south, central, and north. To investigate the seasonal influence of wetlands on streamflow, parameters were grouped on the basis of the four seasons. For each station, the mean parameters for each season were then plotted against their percentages of wetlands.

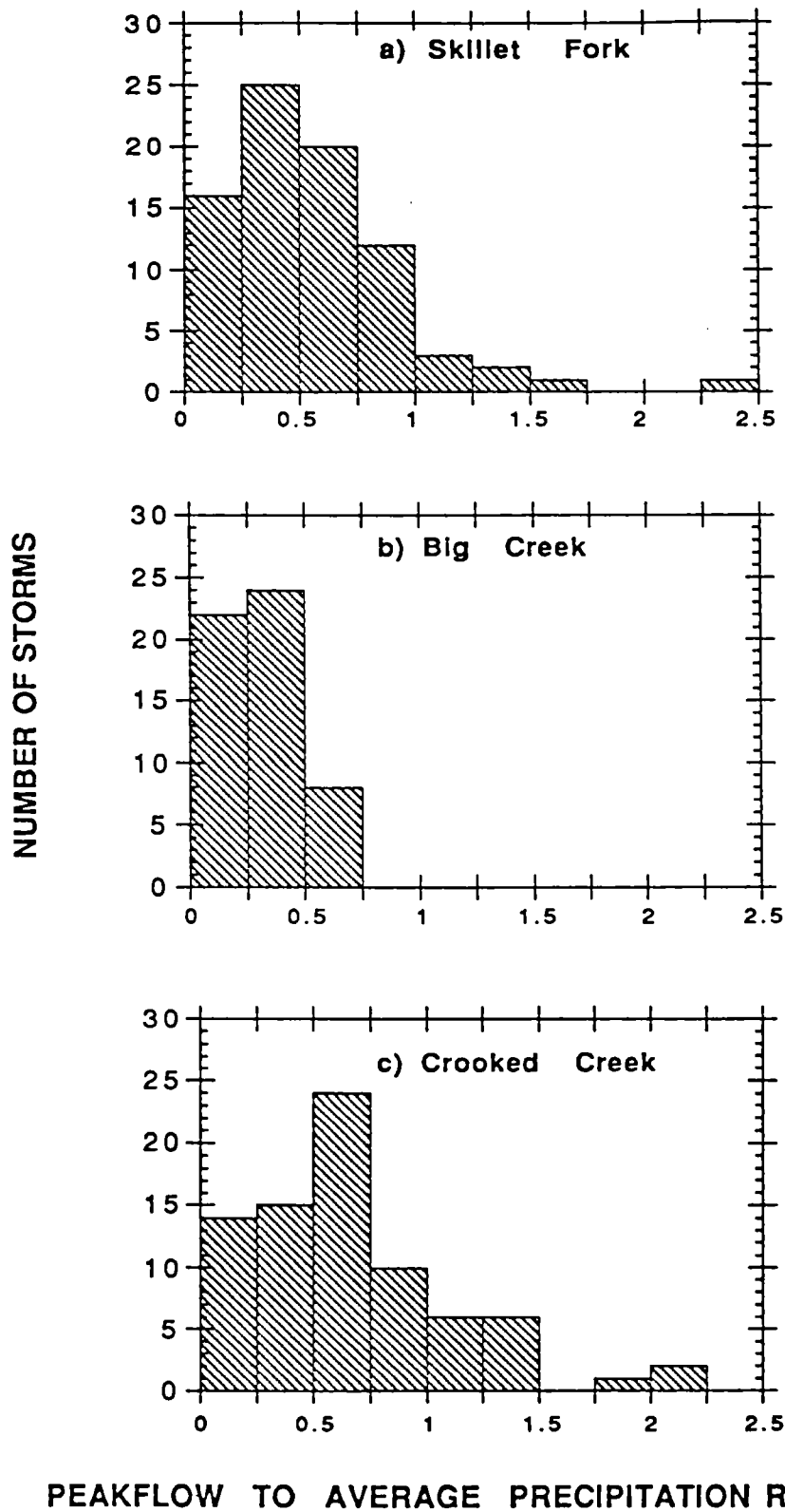


Figure 4. Frequency distribution of storm values of peakflow to average precipitation ratio for three selected stations

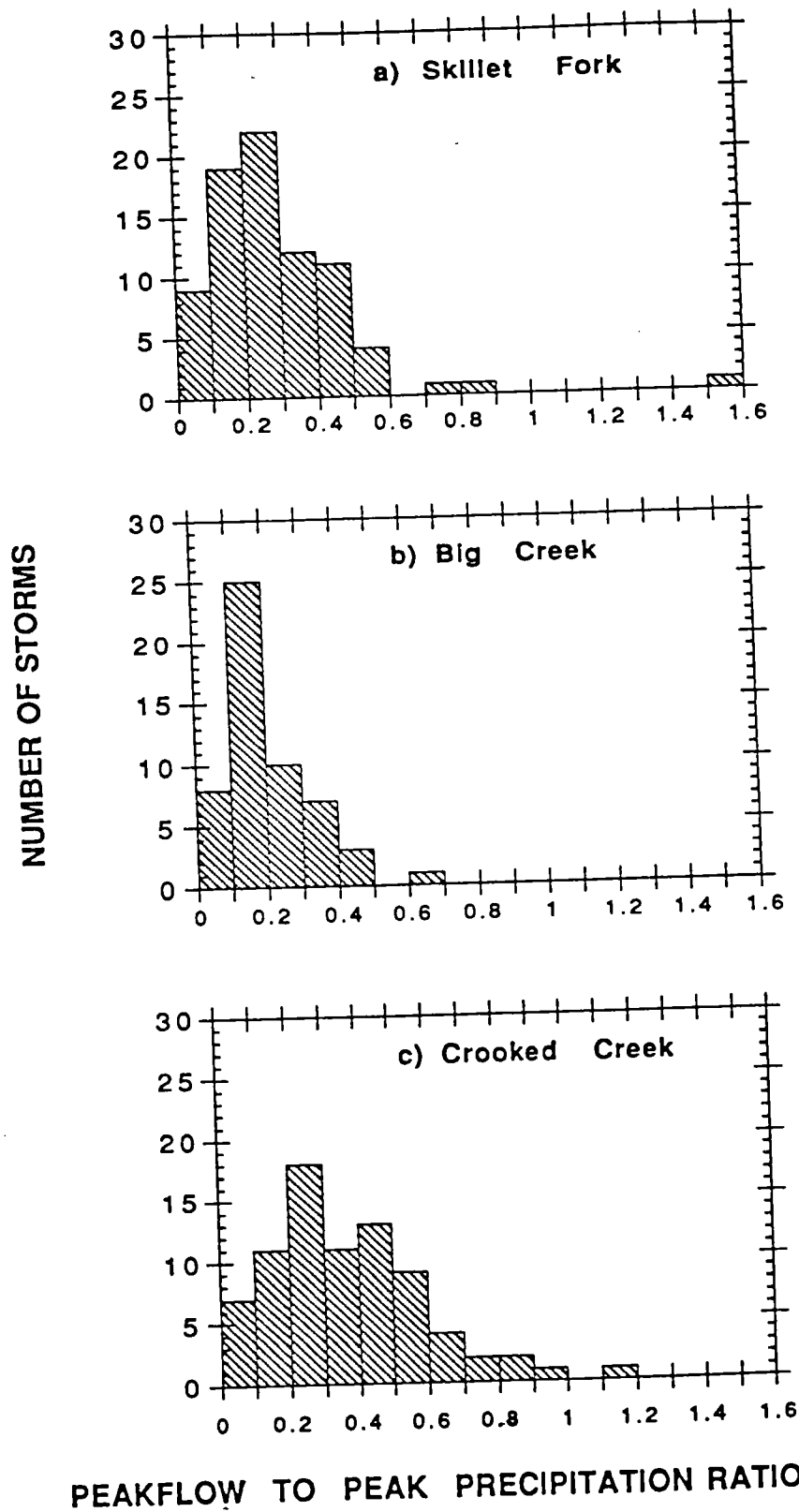
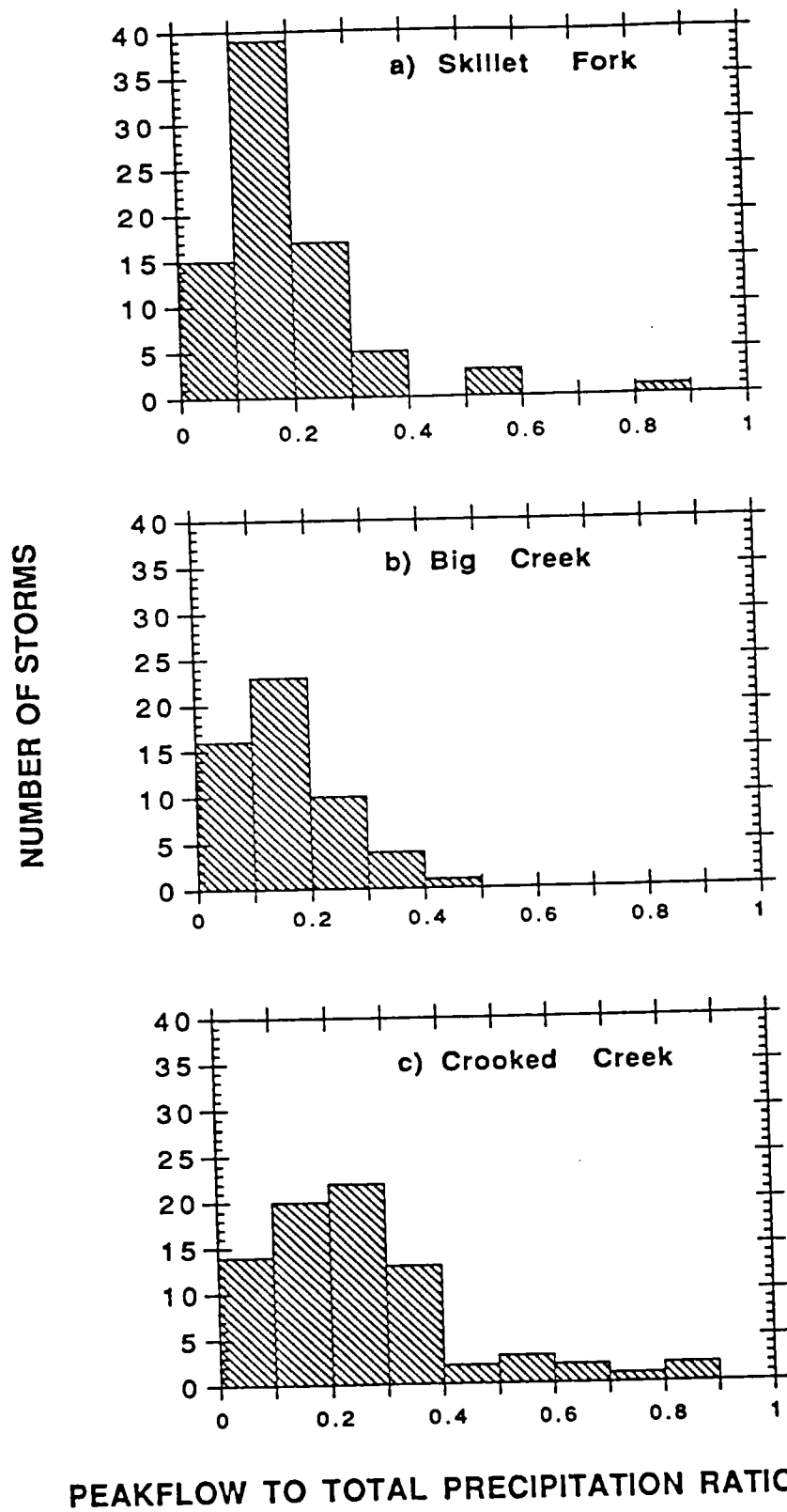


Figure 5. Frequency distribution of storm values of peakflow to peak precipitation ratio for three selected stations



- Figure 6. Frequency distribution of storm values of peakflow to total precipitation ratio for three selected stations

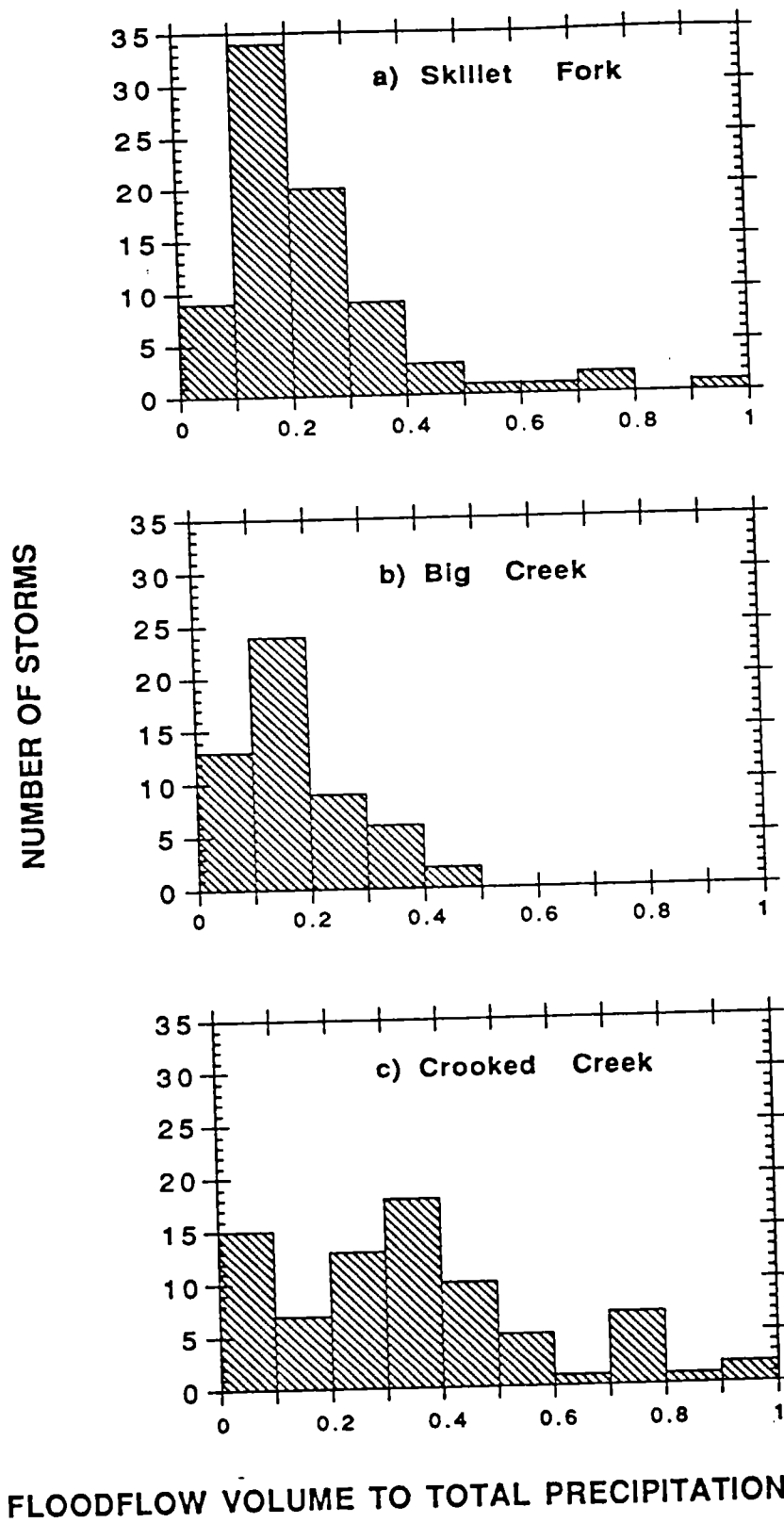


Figure 7. Frequency distribution of floodflow volume to total precipitation ratio for three selected stations

Low Flow. For low-flow analysis, flow duration curves were used. The lower limb of the flow duration curve provides the means to choose a range of low-flow values for analysis. For each watershed, the corresponding flow duration curve was developed by using the daily streamflow data for the selected ten-year period. The low-flow parameters selected for analysis were the discharges at 95 and 99 percent probability of exceedance: Q_{95} and Q_{99} , respectively. The schematics of how the low flows were determined from the flow duration curve are illustrated in figure 8. The low-flow values in cfs were divided by the drainage areas and converted to inches per day. Each low-flow parameter was then plotted against the corresponding percentage of wetlands in the watershed to determine if any relationship existed.

To investigate the regional influence on the low-flow parameters, the parameter values were plotted by grouping the watersheds into the three regions: south, central, and north. To investigate the seasonal influence of wetlands on low flow, flow duration curves were developed and low-flow parameters were computed by grouping the data on the basis of the four seasons. For each station, the low-flow parameters for each season were then plotted against their percentages of wetlands.

Evaluation Procedure

For each flow parameter, the influence of wetlands on streamflow was studied using the linear regression analysis method. Regression analysis is a procedure for fitting an equation to a set of data. For a given set of measurements on two or more variables, regression analysis provides a means for finding coefficients $b_0, b_1, \dots, b_p$ in the regression model of the form:

$$y = b_0 + b_1 x_1 + \dots + b_p x_p \quad (1)$$

where y is the dependent variable and $x_1, \dots, x_p$ are the independent variables. The preceding equation is a general form of the linear multivariate model in which p is the

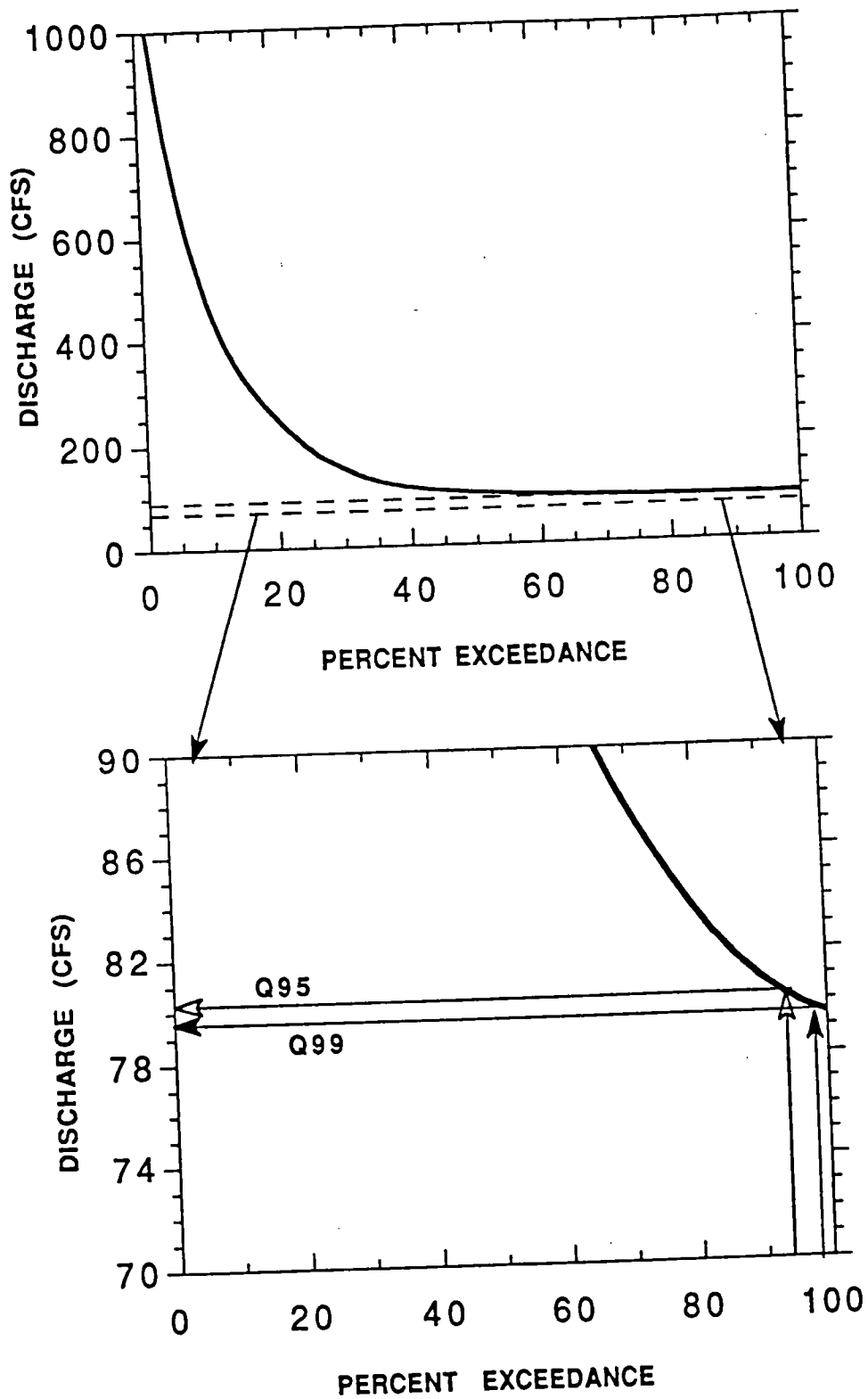


Figure 8. Determination of flows at different exceedance probabilities

number of independent variables, x_i is the i th independent variable, b_i is the i th slope coefficient, and b_0 is the intercept coefficient.

The values of the slopes and intercept in the above equation are computed using the principle of least squares. The principle of least squares is a process of obtaining the best estimate of the coefficients and is referred to as the regression method. Regression is the tendency for the expected value on one or more jointly correlated random variables to approach more closely the mean value of its set than any other. The principle of least squares is used to regress y on x_i values in equation (1). In a least-squares analysis, the error, e , or residual is defined as the difference between the predicted and measured values of the dependent variable:

$$e_i = y_i - \hat{y}_i \quad (2)$$

where $\hat{y}_i$ is the i th predicted value of y , y_i is the i th measured value of y , and e_i is the i th residual or error. The principle of least squares assumes that these errors are independent of each other and are normally distributed having a zero mean and a constant variance.

The objective function to minimize on the basis of the principle of least squares is the sum of squares of the errors, mathematically represented by:

$$F = \sum_{i=1}^n (y_i - \hat{y}_i)^2 \quad (3)$$

where n is the sample size. The function can be minimized by taking the derivative of F with respect to each unknown coefficient, setting these derivatives equal to zero, and then solving for the unknown coefficients.

In this study, percentage of wetlands in the watershed was the only independent variable while the streamflow parameters were the dependent variables.

Testing Method

The influence of wetlands on streamflow was examined by evaluating the percent change in each of the parameters for a one percent change in wetland area. For each flow parameter, a value was selected as the limiting or threshold percent change for an increase of one percent wetland area in the watershed. If the calculated percentage change of the parameter based on the best-fit regression line exceeded this threshold value, then the influence of wetlands on the streamflow parameter was considered to be significant.

The percentage change (PC) for each parameter for an increase of one percent wetland area in the watershed is computed as follows:

$$PC = 100 * S / y_{avg} \quad (4)$$

where S is the slope of the best fit regression line and y_{avg} is the average value of the parameter. The procedure is illustrated in figure 9.

The percent change concept was selected here instead of using the slope of the regression line to provide a meaningful interpretation of the relationship between percent wetland and other hydrologic parameters. Conceptually, PC represents by how much each parameter changes for one percent change in wetland area. We believe this concept is more understandable than providing the rate of change in the peakflow to average precipitation ratio or the floodflow volume to total precipitation ratio.

Based on the observation of the scatter plots and the regression lines of the streamflow parameters, the threshold percentage change was selected to be 0.5 percent. The significance of wetland influence on a streamflow parameter was then decided as follows:

$$|PC| \geq PC_t \rightarrow \text{wetland influence is significant} \quad (5)$$

$$|PC| < PC_t \rightarrow \text{wetland influence is not significant} \quad (6)$$

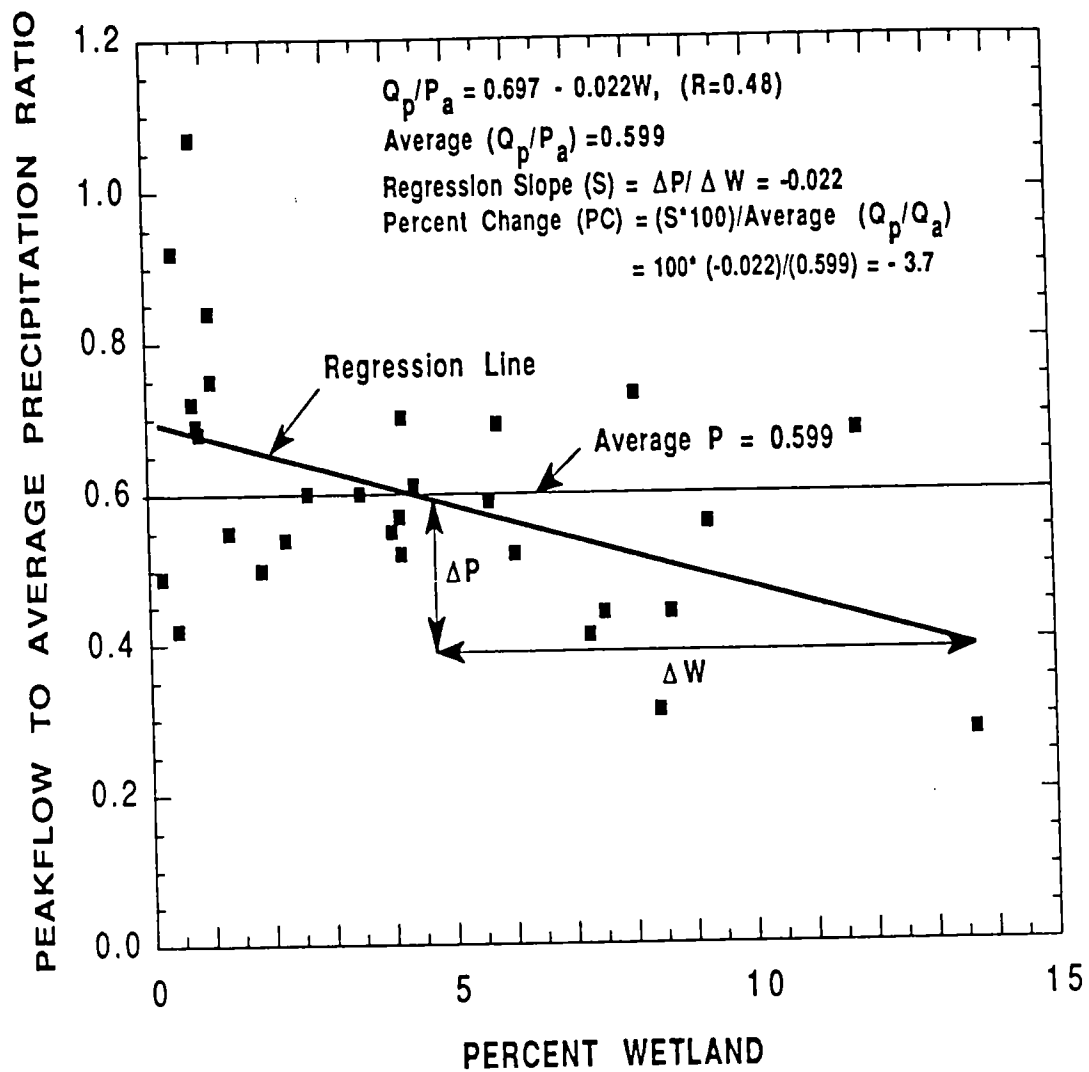


Figure 9. Percent change (PC) determination from regression parameters

where PC is the calculated percentage change for an increase of one percent wetland area in the watershed and PC_t is the threshold percentage change. The symbol $||$ implies absolute value. A positive (+) sign of the computed PC represents an increase in the parameter value and a negative (-) sign of the computed PC represents a decrease in the parameter value with increasing wetland percentage in the watershed.

RESULTS

The results of this study relating changes in peakflow, floodflow volume, and low flow to percent wetland change are presented in this section. The results are based on the statewide analysis where all the stations are included in one group, regional analysis where the stations are grouped into three regions, and seasonal analysis where the data have been segregated for the four seasons.

Peakflow and Floodflow Volume

Statewide Analysis

The results for the statewide analysis are shown in figures 10-13 and table 2. In general, the results of the analysis show that the peakflow and floodflow volume parameters decrease with increasing percentage of wetlands in the watersheds. For an increase of one percent wetland area in the watershed, the corresponding decreases are 3.7 percent for peakflow to average precipitation ratio, 2.6 percent for peakflow to peak precipitation ratio, and 3.0 percent for peakflow to total precipitation ratio. Thus among the three peakflow parameters analyzed, the peakflow to average precipitation ratio shows the most discernible relationship.

Table 2. Regression Analysis Results and Percent Change for Statewide Analysis

<i>Flow parameters</i>	<i>Regression coefficients</i>		<i>Percent change</i>
	<i>Intercept</i>	<i>Slope</i>	
Q_p/P_a	0.696	-0.022	-3.7
Q_p/P_p	0.369	-0.0086	-2.6
Q_p/P_t	0.286	-0.0075	-3.0
V/P_t	0.318	-0.0041	-1.4

The floodflow volume to total precipitation ratio decreases by 1.4 percent for an increase of one percent wetland area in the watershed (figure 13). The decrease in the floodflow volume parameter is significantly lower than for the peakflow parameters.

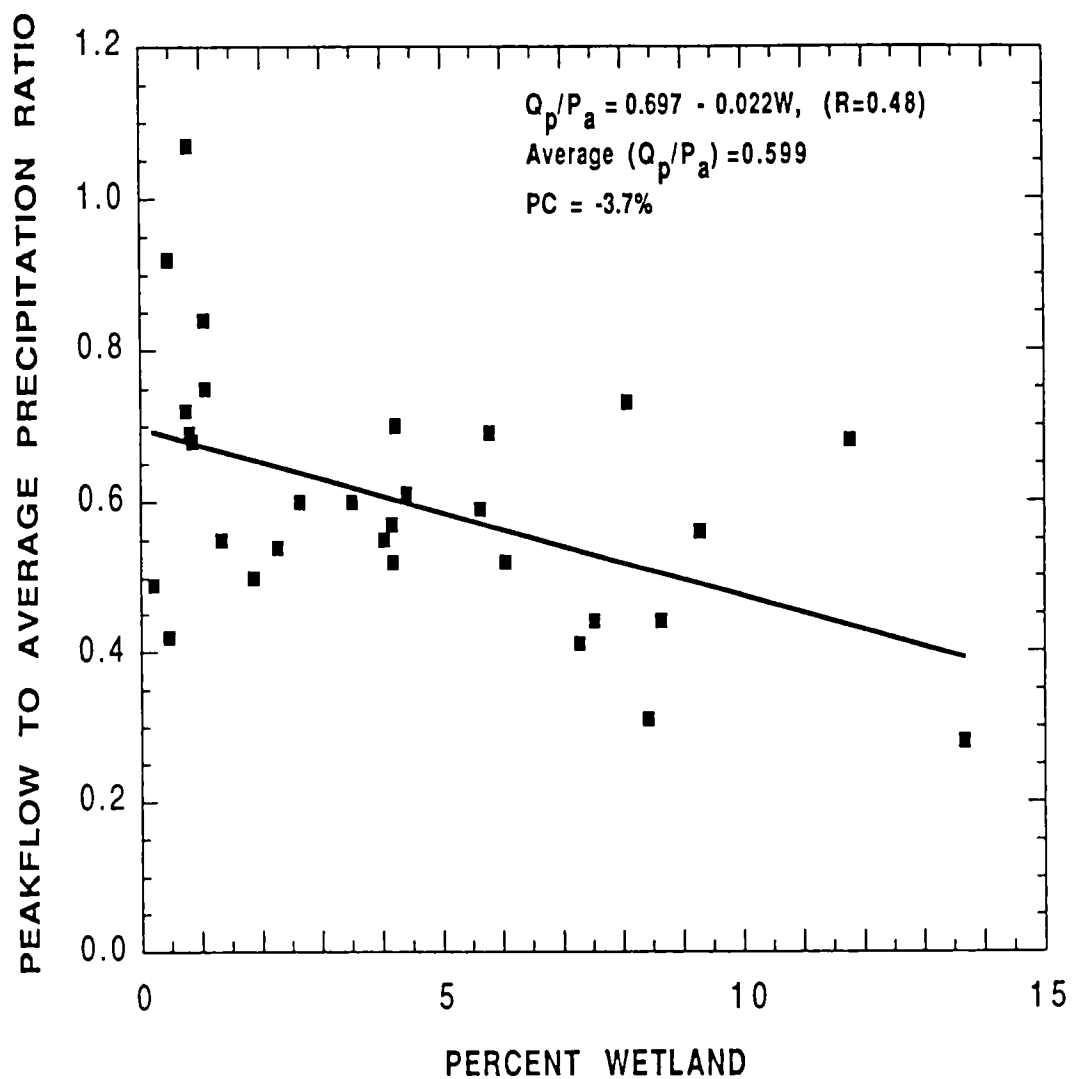


Figure 10. Relation between peakflow to average precipitation ratio and percent wetland for Illinois

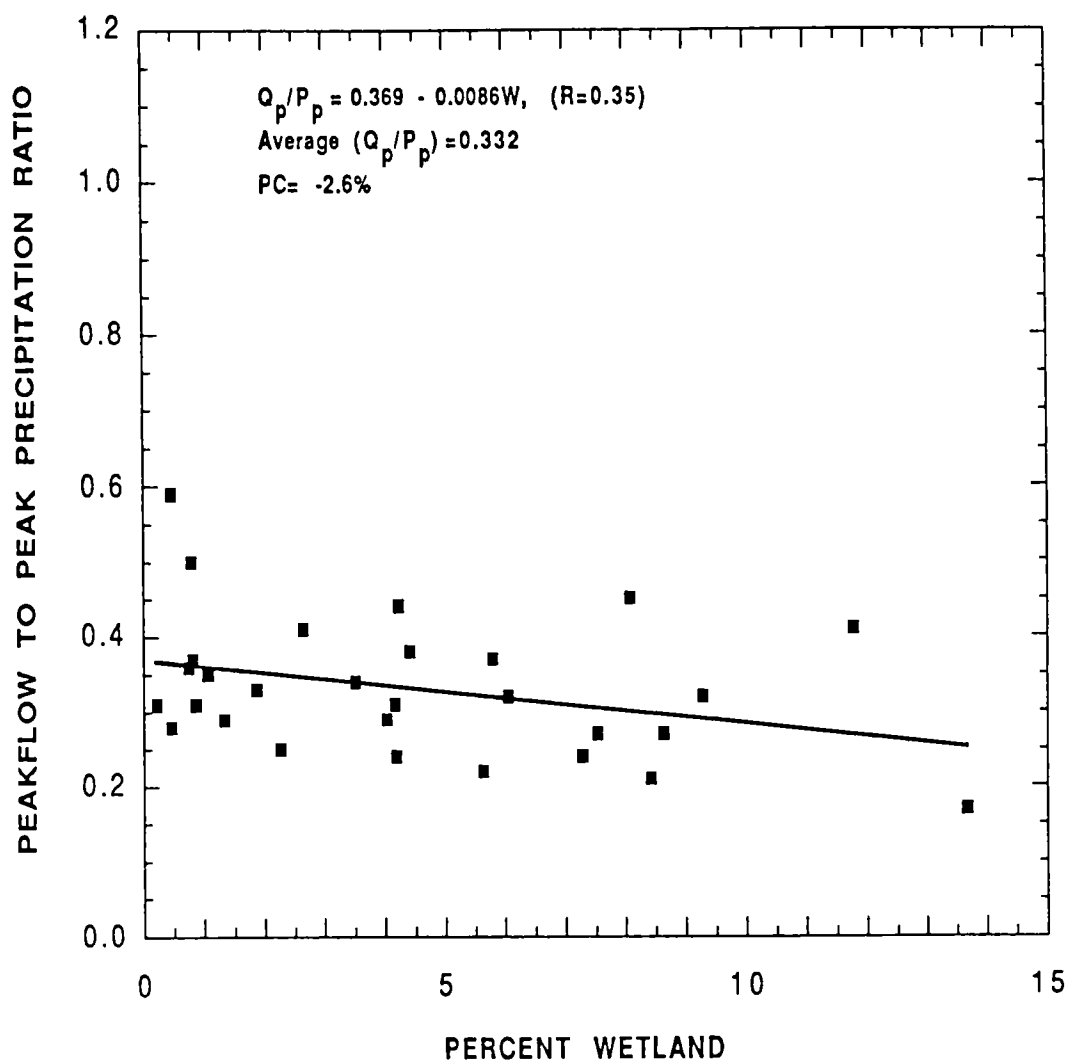


Figure 11. Relation between peakflow to peak precipitation ratio and percent wetland for Illinois

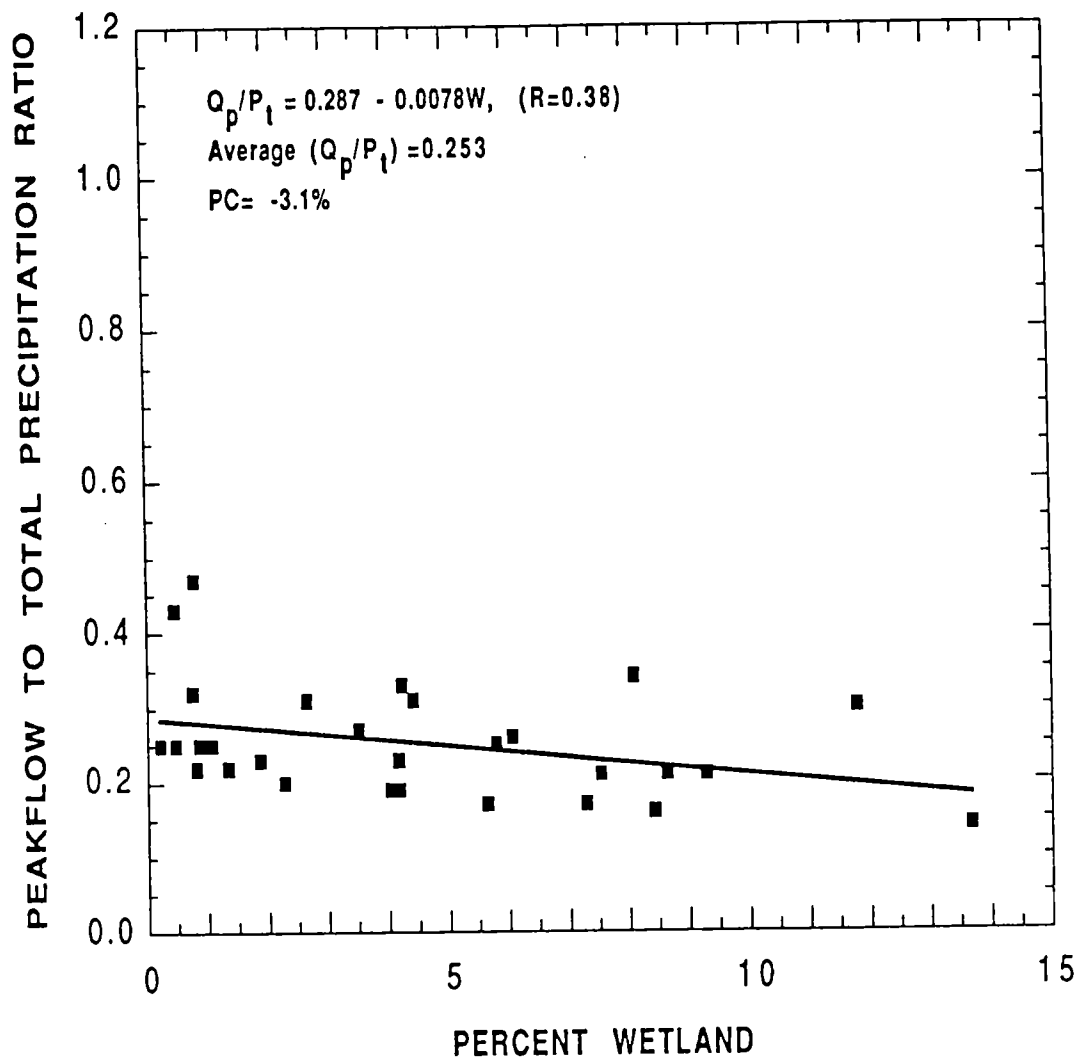


Figure 12. Relation between peakflow to total precipitation ratio and percent wetland for Illinois

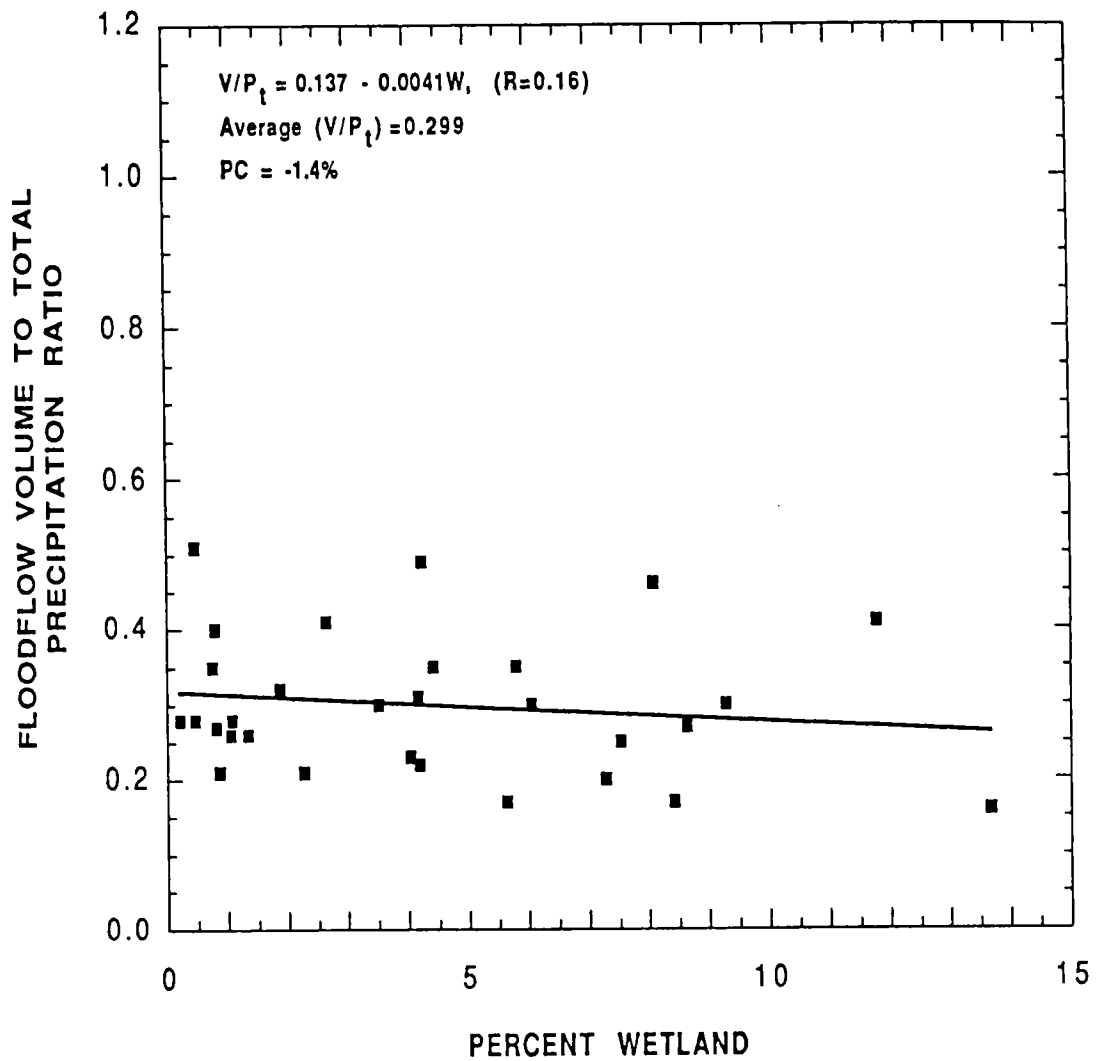


Figure 13. Relation between floodflow volume to total precipitation ratio and percent wetland for Illinois

Regional Analysis

The results from the regional analysis are summarized in figure 14 and table 3. The relations between the three peakflow parameters and percent wetland for the three regions are compared with the relation for the statewide analysis in figures 14a-14c. The analysis indicates that all three peakflow parameters decrease with increasing percentage of wetlands for central and northern Illinois. The peakflow to average precipitation ratio shows the most significant relationship. The percent decreases for central Illinois are 5.9, 4.9, and 5.0 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively. For northern Illinois the decreases for the three peakflow parameters are 7.9, 6.5, and 2.9 percent, respectively.

Table 3. Regional Regression Coefficients and Percent Change Values for Peakflow and Floodflow Parameters

<i>Flow parameter</i>	<i>Regression parameters</i>		<i>Slope</i>	<i>Percent change</i>
	<i>Region</i>	<i>Intercept</i>		
Q_p/P_a	statewide	0.696	-2.22	-3.7
	southern	0.601	0.53	0.8
	central	0.673	-3.29	-5.9
	northern	0.797	-4.78	-7.9
Q_p/P_p	statewide	0.369	-0.86	-2.6
	southern	0.320	0.57	1.6
	central	0.350	-1.44	-4.9
	northern	0.427	-2.20	-6.5
V/P_t	statewide	0.318	-0.41	-1.4
	southern	0.355	0.00	0.0
	central	0.294	-1.10	-5.9
	northern	0.304	-0.70	-7.9

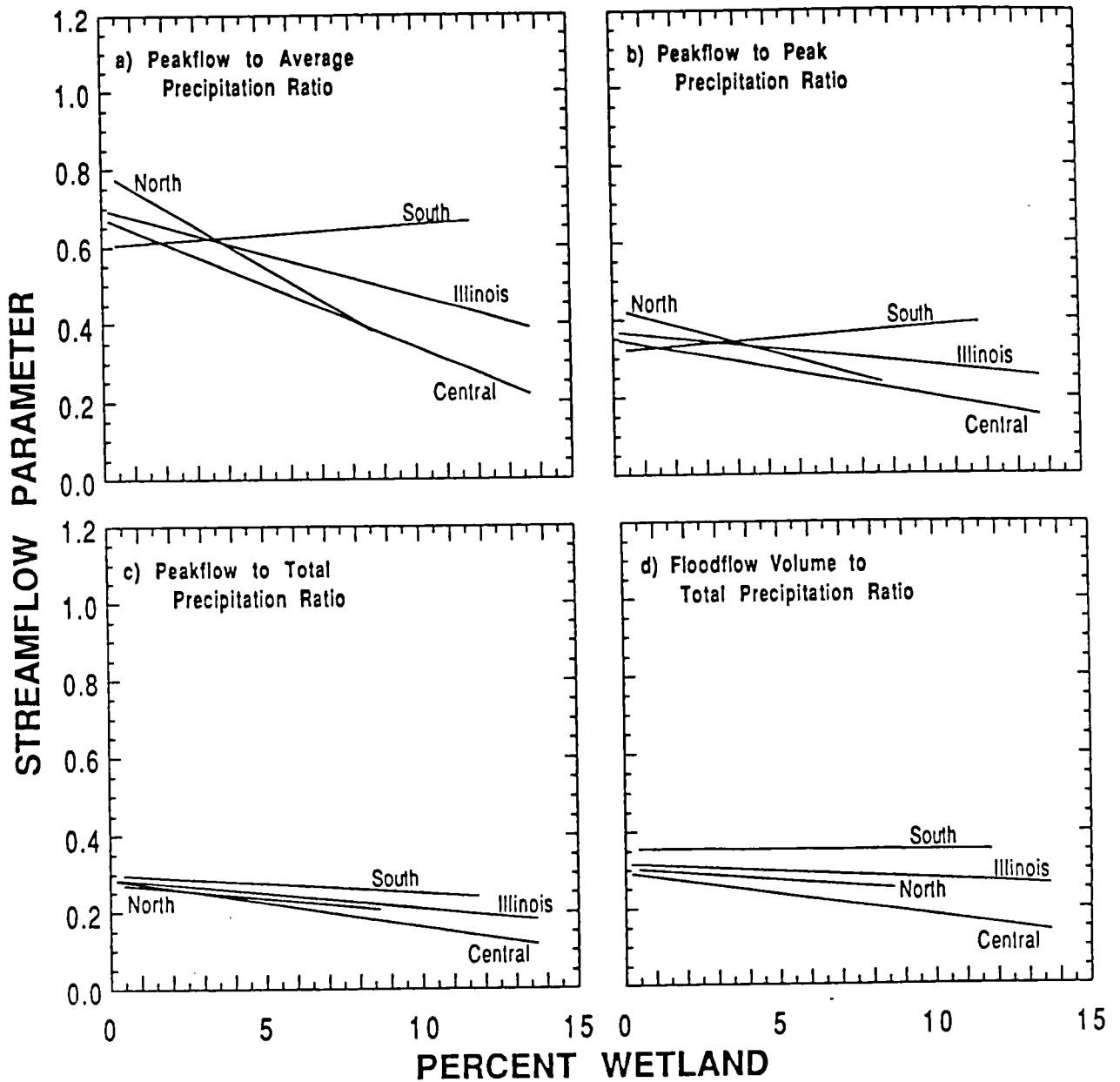


Figure 14. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland

In southern Illinois, peakflow to average precipitation ratio and peakflow to peak precipitation ratio increase by 0.8 and 1.6 percent, respectively, while peakflow to total precipitation ratio decreases by 1.9 percent. Thus, the relationships for southern Illinois are less noticeable and contradictory than those for central and northern Illinois.

The relations between the floodflow volume parameters and percent wetland for the three regions are compared in figure 14d. The floodflow volume to total precipitation ratio decreases for central and northern Illinois by 4.5 and 2.3 percent, respectively. For southern Illinois, however, the percentage of wetlands appears to have no influence on the floodflow volume ratio; it essentially remains constant irrespective of the percentage of wetlands in the watershed.

Seasonal Analysis

The influence of wetlands on streamflow could depend on seasonal variation of wetland functions and the general hydrologic cycle of precipitation, infiltration, storage, and runoff. In Illinois seasonal variations in precipitation, soil moisture and runoff are significant. Therefore it was decided to evaluate if significant differences in the influence of wetlands on streamflow could be detected based on available streamflow data. The selected flood events were grouped in the season they occurred and similar analyses were performed to evaluate the differences. The results are also compared to the total set of data.

The results from the seasonal analysis are summarized in figures 15-19 and tables 4-7. The seasonal analysis indicates that all three peakflow parameters decrease with increasing percentage of wetlands for all seasons. The greatest decrease is found in the fall and the least during winter. The percent decreases in fall, for an increase of one percent wetland area in the watershed, are 5.7, 4.1, and 5.6 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively. The corresponding values for winter are 2.4, 1.6, and 1.4

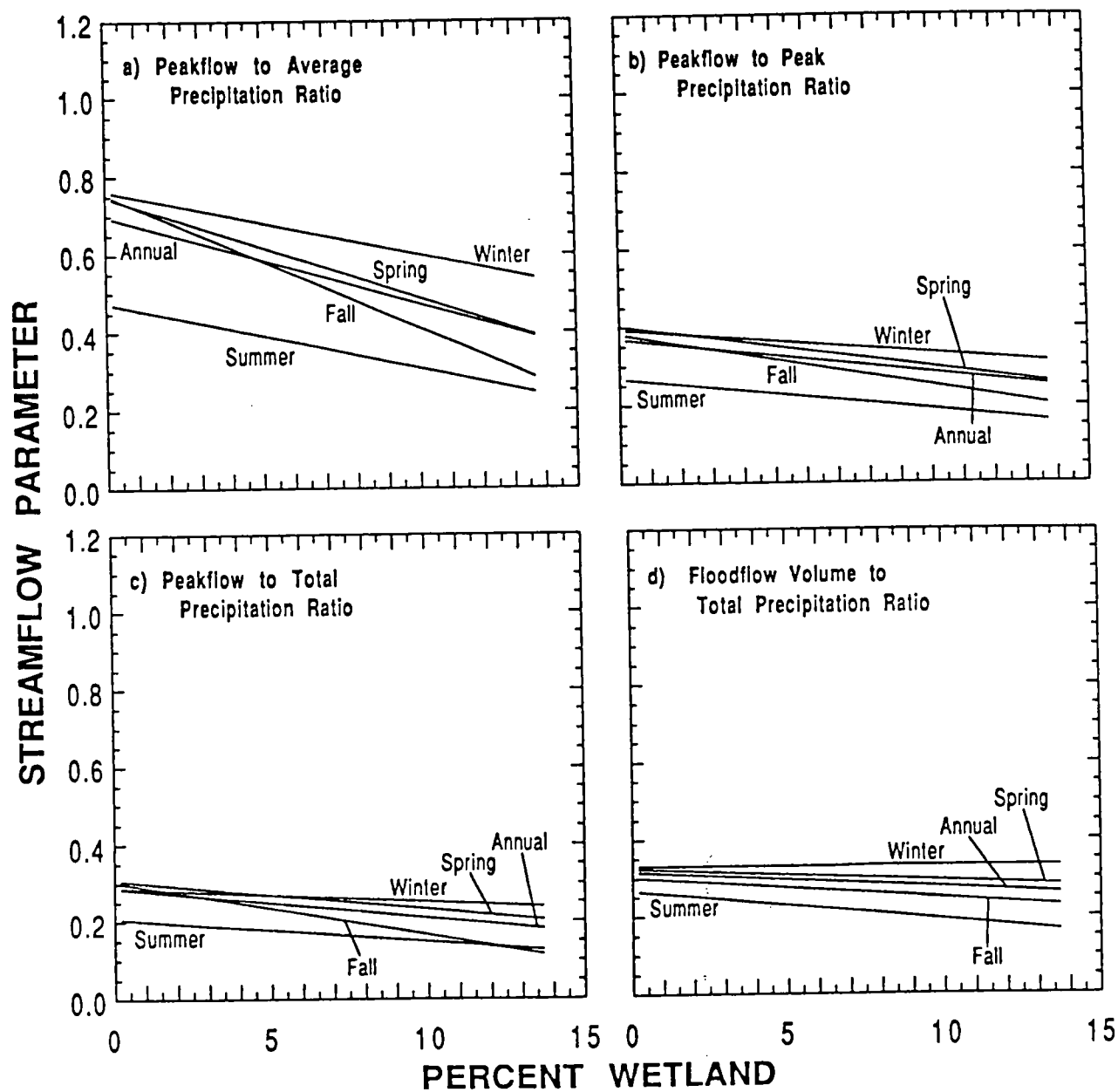


Figure 15. Seasonal variation of the relations between peakflow and floodflow volume parameters and percent wetland

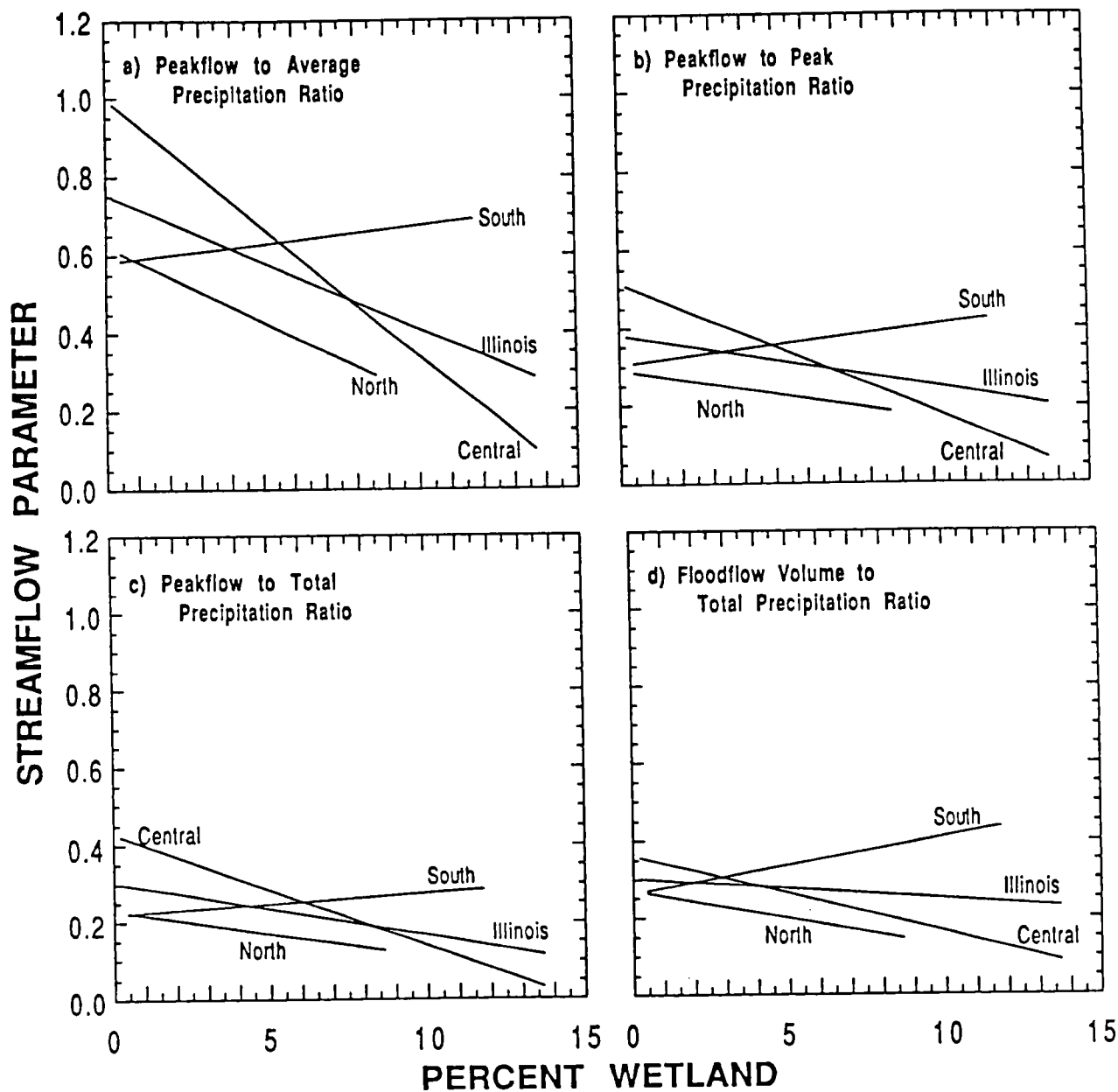


Figure 16. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for fall

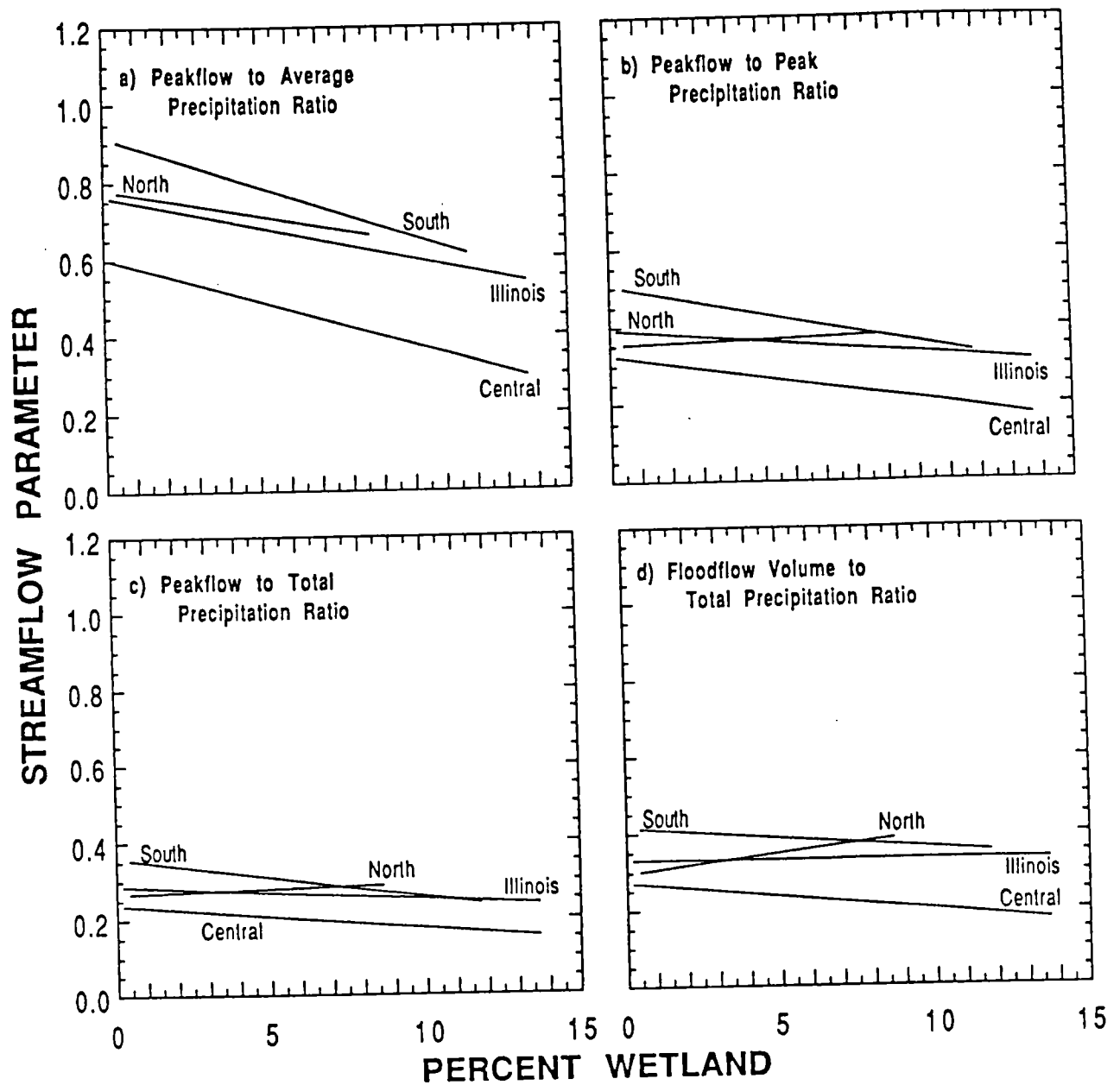


Figure 17. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for winter

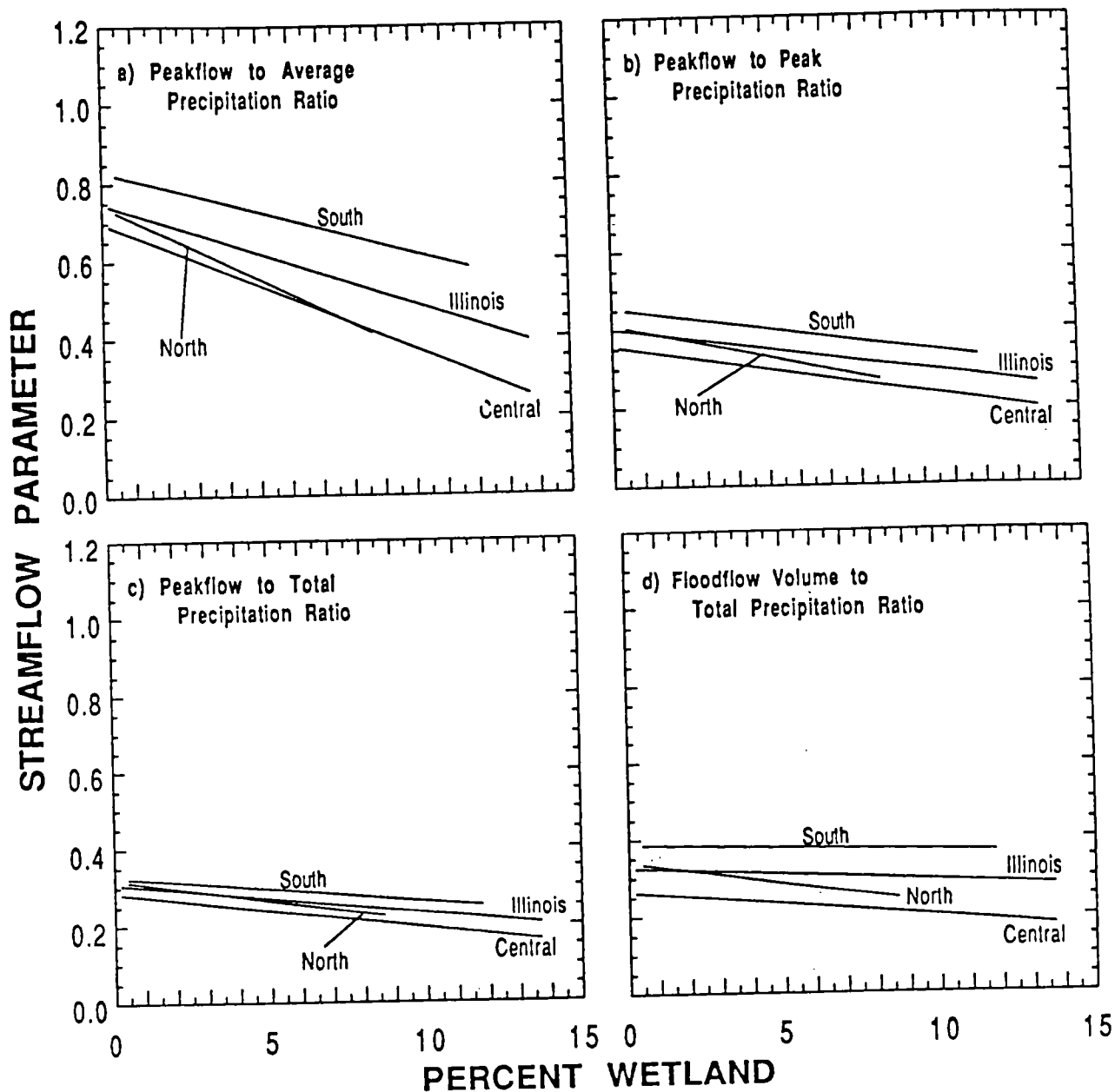


Figure 18. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for spring

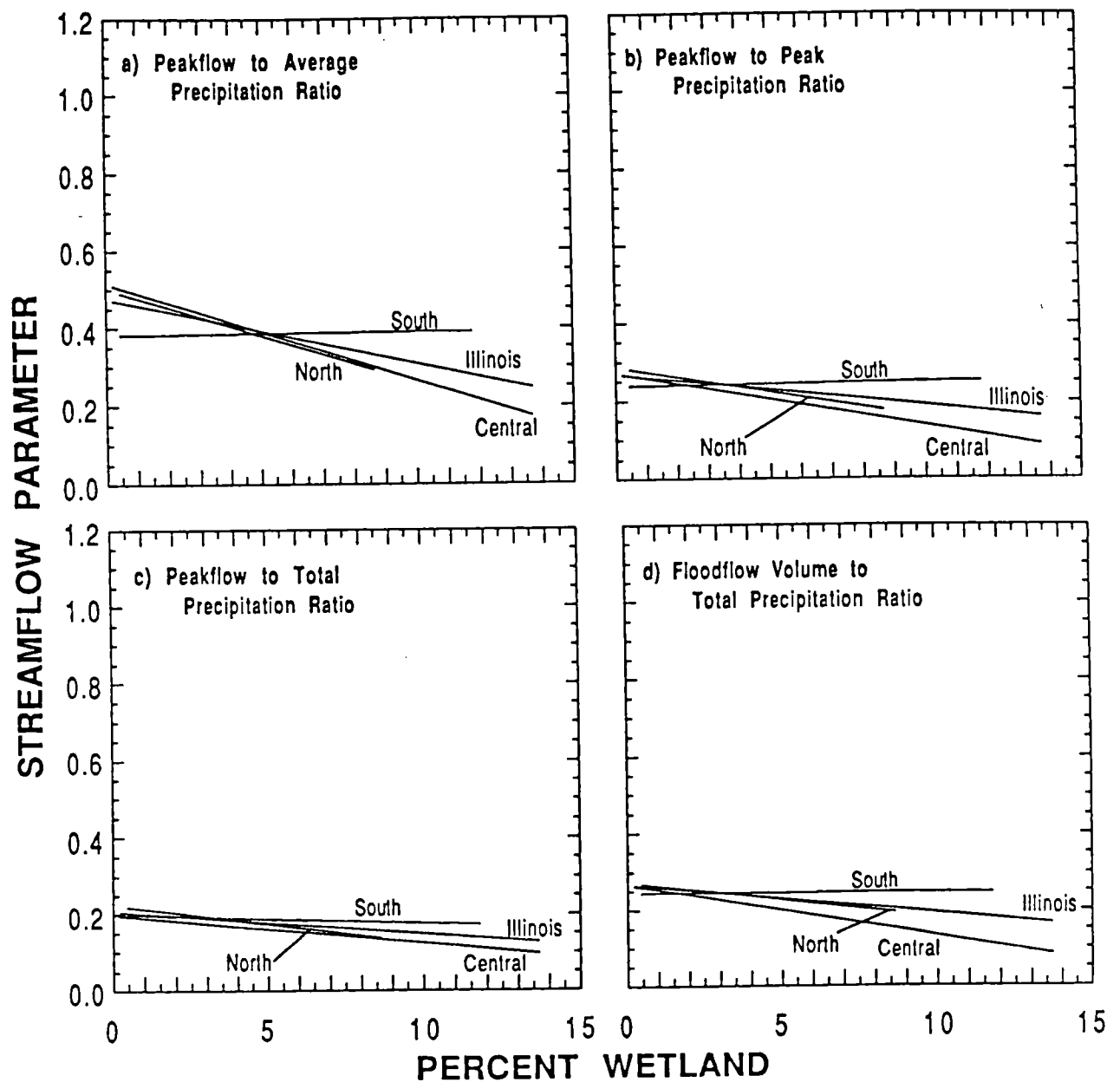


Figure 19. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for summer

Table 4. Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Average Precipitation Ratio (Q_p/P_a) for a One Percent Change in Wetland Area

	<i>Annual</i>	<i>Fall</i>	<i>Winter</i>	<i>Spring</i>	<i>Summer</i>
Illinois (statewide)	-3.7	-5.7	-2.4	-4.0	-4.2
South	+0.8	+1.5	-3.3	-2.9	+0.3
Central	-5.9	-8.7	-4.3	-5.3	-5.9
North	-7.9	-8.2	-1.9	-6.5	-6.1

Table 5. Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Peak Precipitation (Q_p/P_p) for a One Percent Change in Wetland Area

	<i>Annual</i>	<i>Fall</i>	<i>Winter</i>	<i>Spring</i>	<i>Summer</i>
Illinois (statewide)	-2.6	-4.1	-1.6	-2.8	-3.8
South	1.6	2.7	-3.4	-2.7	+0.5
Central	-4.9	-8.3	-4.0	-3.6	-6.0
North	-6.5	-5.1	0.8	-4.6	-5.5

Table 6. Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Total Precipitation (Q_p/P_t) for a One Percent Change in Wetland Area

	<i>Annual</i>	<i>Fall</i>	<i>Winter</i>	<i>Spring</i>	<i>Summer</i>
Illinois (statewide)	-3.0	-5.6	-1.4	-2.7	-3.4
South	-1.9	2.3	-3.5	-2.2	-1.4
Central	-5.0	-9.0	-3.0	-3.5	-4.4
North	-2.9	-6.2	0.9	-3.8	-5.6

Table 7. Influence of Wetlands on Floodflow Volume as Measured by the Percent Change in the Ratio of Floodflow Volume to Total Precipitation (V/P_t) for a One Percent Change in Wetland Area

	<i>Annual</i>	<i>Fall</i>	<i>Winter</i>	<i>Spring</i>	<i>Summer</i>
Illinois (statewide)	-1.4	-2.0	0.0	-1.0	-3.1
South	0.0	+4.4	-1.5	-0.6	+0.2
Central	-5.9	-8.7	-4.3	-5.3	-5.9
North	-7.9	-8.2	-1.9	-6.5	-6.1

percent. The decreases in peakflow parameters for spring and summer are very similar; for spring, the decreases are 4.0, 2.8, and 2.7 percent; and for summer, the decreases are 4.2, 3.4, and 3.4 percent. The peakflow ratios for the four seasons are compared in figures 15a-15c.

The relationships for the floodflow volume parameter are much less perceptible than those for the peakflow parameter. The decreases for floodflow volume for fall, winter, spring, and summer are 2.0, 0.0, 1.0, and 3.1 percent, respectively. Figure 15d compares the floodflow volume ratio for the four seasons.

Seasonal-Regional

Since the storm events were separated on the basis of the season in which they occurred for the seasonal analysis discussed in the preceding section, it was decided to evaluate if the general seasonal patterns vary from region to region within Illinois. In a similar fashion as was done for the regional analysis, the data for the seasonal analysis were grouped into regions to assess the seasonal influence in different regions of the state. A summary of the statewide analysis is provided in the seasonal analysis discussed in the preceding section. The regional aspect of the seasonal analysis is presented in the following sections. The results of this analysis are provided in figures 16-19 and tables 4-7.

Fall. The results for the fall season are shown in figure 16. The results show that all the peakflow parameters decrease with increasing percentage of wetlands for both central and northern Illinois. The decreases for central Illinois are 8.7, 8.3, and 9.0 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively. The decreases for northern Illinois are 8.2, 5.1, and 6.2 percent, respectively. For southern Illinois, however, the peakflow ratios increase with increasing percentage of wetlands: the increases are 1.5, 2.7, and 2.3 percent, respectively. Among the three peakflow parameters, the most noticeable

relationship is for the peakflow to average precipitation ratio. Among the three regions, the relationships for central and northern Illinois are more perceptible.

The floodflow volume parameter exhibits results similar to the peakflow parameters, where the parameter decreases in northern and central Illinois and increases in southern Illinois (figure 16c). The decreases for central and northern Illinois are 6.9 percent and the increase for southern Illinois is 4.4 percent.

Winter. The results for the winter season are summarized in figure 17. The results show that, in general, the peakflow parameters decrease with increasing percentage of wetlands in the watershed for southern and central Illinois. The decreases for southern Illinois are 3.3, 3.4, and 3.5 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively. The decreases for central Illinois are 4.3, 4.0, and 3.0 percent, respectively. For northern Illinois, only peakflow to average precipitation ratio decreases by 1.9 percent, while peakflow to peak precipitation ratio and peakflow to total precipitation ratio increase by 0.8 and 0.9 percent, respectively. Among the three peakflow parameters, the most noticeable relationship is for peakflow to average precipitation ratio. Among the three regions, the relationship for central Illinois is the most perceptible.

The floodflow volume parameter exhibits similar results to those of the peakflow parameters (figure 16d). The floodflow volume to total precipitation ratio decreases by 1.5 and 3.0 percent for southern and central Illinois, and increases by 3.1 percent for northern Illinois.

Spring. The results for the spring season are shown in figure 18. The results show that the peakflow parameters decrease with increasing percentage of wetlands for all three regions. The decreases for southern Illinois are 2.9, 2.7, and 2.2 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively, for an increase of one percent wetland area in the watershed. The corresponding decreases for central Illinois are 5.3, 3.6, and

3.5 percent and for northern Illinois they are 6.5, 4.6, and 3.8 percent. Among the three peakflow ratios, the most significant relationship is for peakflow to average precipitation ratio. Among the three regions, the relationship for northern Illinois is the most perceptible.

The floodflow volume parameter also decreases with increasing wetland percentage for all three regions (figure 18d). The decreases are 0.6, 2.3, and 3.7 percent for southern, central, and northern Illinois, respectively.

Summer. The results for the summer season are shown in figure 19. The results show that the peakflow parameters decrease with increasing percentage of wetlands in the watershed for central and northern Illinois. The decreases for central Illinois are 5.9, 6.0, and 4.4 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively, for an increase of one percent wetland area in the watershed. The corresponding decreases for northern Illinois are 6.1, 5.5, and 5.6, for southern Illinois, peakflow to average precipitation ratio is not significantly influenced by the presence of wetlands, peakflow to peak precipitation ratio increases by 0.5 percent, while peakflow to total precipitation ratio decreases by 1.4 percent. Among the three peakflow ratios, the most significant relationship is for peakflow to average precipitation ratio. Among the three regions, the relationship for central and northern Illinois are more perceptible.

Similar to the peakflow parameters, the floodflow volume parameters also decrease by 6.1 and 4.1 percent for central and northern Illinois, respectively. For southern Illinois, however, floodflow volume is not significantly affected by the percentage of wetlands in the watershed.

Low Flow

Statewide Analysis

The results from the low-flow analysis for the state as a whole are shown in figures 20-21 and tables 8 and 9. The results indicate that flows at both 95 and 99 percent probability of exceedance (Q₉₅ and Q₉₉) generally increase with increasing wetland percentage in the watershed. For the whole state, the percent increases for Q₉₅ and Q₉₉ for an increase of one percent wetland area in the watershed are 7.9 and 8.4 percent, respectively. As figures 20 and 21 show, there is a wide scatter in the data points for both Q₉₅ and Q₉₉ for Illinois as a whole; however, the scatter in the data can be considerably reduced for both the low-flow parameters when they are grouped on a regional basis.

Regional Analysis

The results from the regional analysis are also shown in figures 20-21 and table 8. The results indicate that both low-flow parameters increase with increasing percentage of wetlands. The percent increases for Q₉₅ and Q₉₉ for southern Illinois are 15.9 and 17.2 percent, respectively. For northern Illinois, the increases are 15.0 and 18.2 percent, respectively. The influence of wetlands on low flow is significantly less in central Illinois compared to that in either southern or northern Illinois. Q₉₅ increased by 5.5 percent, while Q₉₉ shows a decrease of 4.6 percent. Thus, based on the data analyzed, influence of wetlands on low flow is more dominant in southern and northern Illinois than in central Illinois.

Seasonal Analysis

The results from the seasonal analysis are shown in figure 22 and table 9. The seasonal analysis indicates that both Q₉₅ and Q₉₉ increase with increasing wetland percentage for fall. The percent increases in fall are 8.4 and 9.2 percent for Q₉₅ and Q₉₉, respectively. The relationships are similar for winter and summer. The percent increases

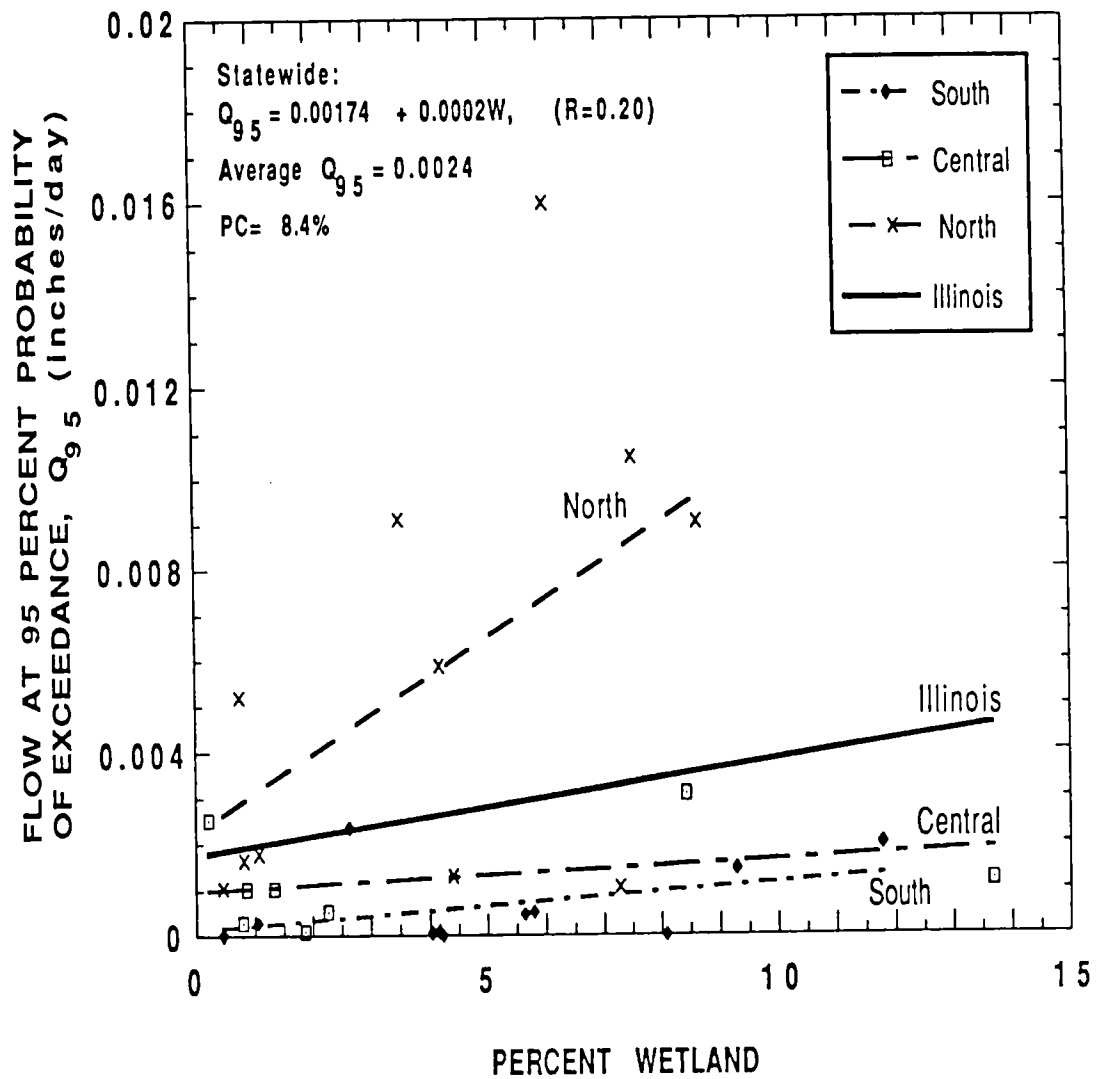


Figure 20. Relation between low-flow parameter, Q_{95} , and percent wetland for Illinois

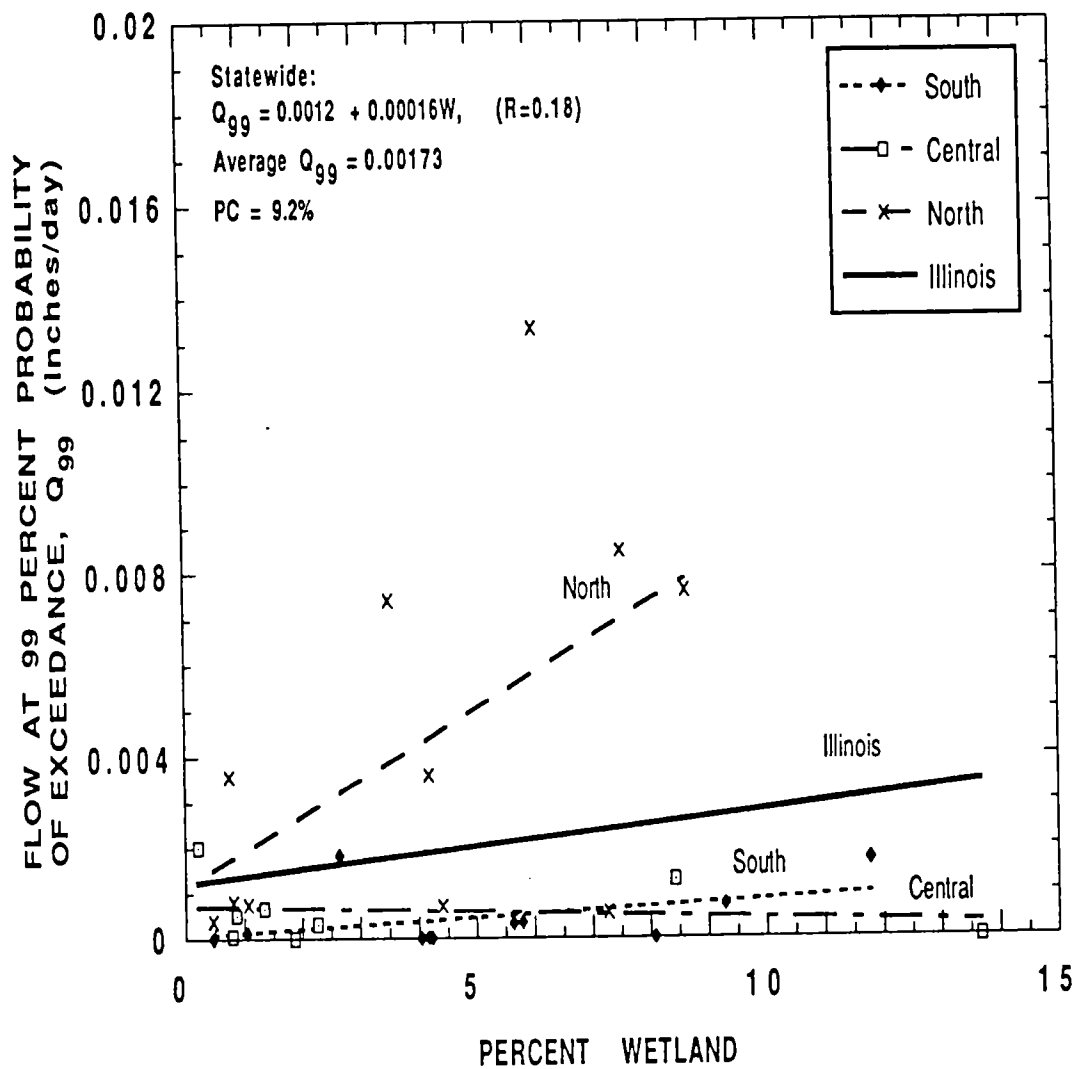


Figure 21. Relation between low-flow parameter, Q_{99} , and percent wetland for Illinois

Table 8. Regional Variability of Influence of Wetlands on Low Flow in Illinois
as Measured by the Percent Change in Q95 and Q99

	<i>Q95</i> (percent change)	<i>Q99</i> (percent change)
Illinois (statewide)	+7.9	+8.4
Southern Illinois	+15.9	+17.2
Central Illinois	+5.5	-4.6
Northern Illinois	+15.0	+18.2

Table 9. Seasonal Variability of Influence of Wetlands on Low Flow in Illinois
as Measured by the Percent Change in Q95 and Q99

	<i>Q95</i> (percent change)	<i>Q99</i> (percent change)
Annual	+7.9	+8.4
Fall	+8.4	+9.2
Winter	+7.6	+7.6
Spring	-1.8	-2.4
Summer	+8.0	+9.4

Notes:

Q95 = flow at 95 percent probability of exceedance

Q99 = flow at 99 percent probability of exceedance

+ = parameter value increases with increasing wetland percentage

- = parameter value decreases with increasing wetland percentage

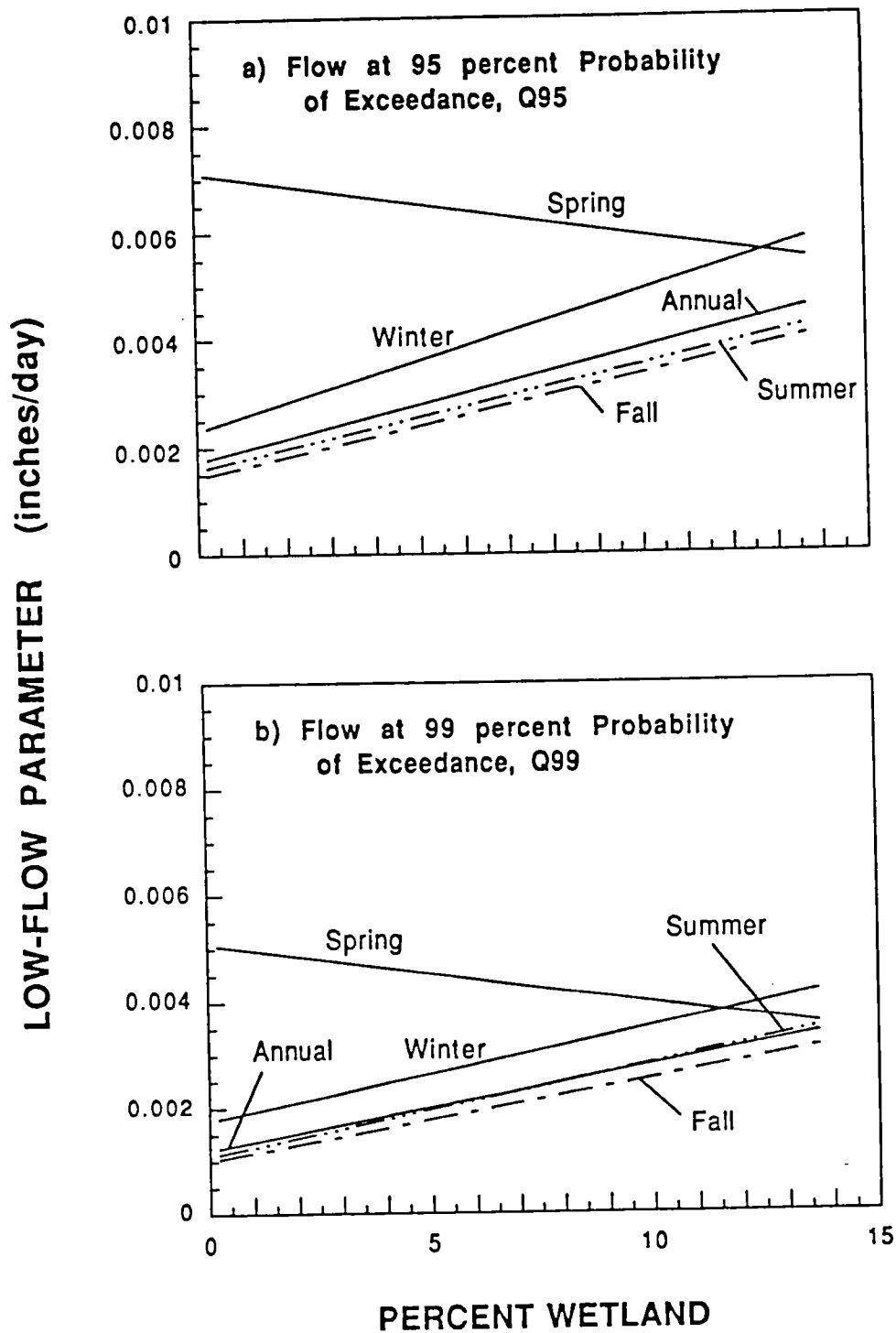


Figure 22. Seasonal variation of the relation between parameters Q95 and Q99 and percent wetland low flow

in winter are 7.6 percent for both Q95 and Q99, while the percent increases in summer are 8.0 and 9.4 percent for Q95 and Q99, respectively. For spring, however, Q95 and Q99 decrease by 1.8 and 2.4 percent, respectively.

Seasonal-Regional

As mentioned previously, low-flow parameters were computed for each season by grouping the data on the basis of the four seasons. The following sections discuss the seasonal influence for the different regions. The results of this analysis are summarized in table 10.

Fall. The results show that both Q95 and Q99 increase with increasing wetland percentage in the watershed for southern as well as northern Illinois. The increases for southern Illinois are 17.2 and 19.3 percent for Q95 and Q99, respectively. The increases for northern Illinois are 15.6 and 18.7 percent, respectively. For central Illinois, however, Q95 increases by 6.4 percent, while Q99 decreases by 2.8 percent. Thus the relationships for southern and northern Illinois show more influence of wetlands on low flow compared to central Illinois for fall. The rate of increase is, however, much higher for northern Illinois than that for southern Illinois.

Winter. The results show that both Q95 and Q99 increase with increasing wetland percentage in the watershed for all three regions: southern, central, and northern Illinois during winter. The percent increases for southern Illinois are 9.1 and 8.9 percent for Q95 and Q99, respectively. The percent increases for central Illinois are 10.2 and 5.7 percent, respectively. The percent increases for northern Illinois are 12.9 and 14.1 percent, respectively. Thus the relationships for all three regions in Illinois show similar influence of wetlands on low flow for winter. The rate of increase is again higher for northern Illinois than that for either southern or central Illinois.

Spring. The results show that for all three regions - southern, central, and northern Illinois - Q95 as well as Q99 are influenced much less by wetlands in spring than

Table 10. Seasonal Variability of Influence of Wetlands on Low Flow by Region
in Illinois as Measured by the Percent Change in Q95 and Q99

	<i>Fall</i>		<i>Winter</i>		<i>Spring</i>		<i>Summer</i>	
	<i>Q95</i>	<i>Q99</i>	<i>Q95</i>	<i>Q99</i>	<i>Q95</i>	<i>Q99</i>	<i>Q95</i>	<i>Q99</i>
Illinois	+8.4	+9.2	+7.6	+7.0	-1.8	-2.4	+8.0	+9.4
Southern Illinois	+17.2	+19.3	+9.1	+8.9	-0.4	+5.3	+22.0	+20.9
Central Illinois	+6.4	-2.8	+10.2	+5.7	-2.1	-4.2	-4.7	-8.0
Northern Illinois	+15.6	+18.7	+12.9	+14.1	+3.8	+2.2	+16.2	+20.0

Notes:

Q95= flow at 95 percent probability of exceedance

Q99= flow at 99 percent probability of exceedance

+ = parameter value increases with increasing wetland percentage

- = parameter value decreases with increasing wetland percentage

in the other seasons. For southern Illinois, Q₉₅ is not significantly influenced by wetlands in spring, while Q₉₉ shows an increase of 5.3 percent. For central Illinois, there are decreases of 2.1 and 4.2 percent for Q₉₅ and Q₉₉, respectively. For northern Illinois, there are increases of 3.8 and 2.2 percent for Q₉₅ and Q₉₉, respectively.

Summer. The results show that both Q₉₅ and Q₉₉ increase with increasing wetland percentage in the watershed for southern as well as northern Illinois. The increases for southern Illinois are 22.0 and 20.9 percent for Q₉₅ and Q₉₉, respectively. The increases for northern Illinois are 16.2 and 20.0 percent, respectively. For central Illinois, however, Q₉₅ and Q₉₉ decreases by 4.7 and 8.0 percent, respectively. Thus the relationships for southern and northern Illinois show more influence of wetlands on low flow compared to central Illinois. The rate of increase is again much higher for northern Illinois than that for southern Illinois.

SUMMARY AND CONCLUSIONS

Existing streamflow records from 30 gaging stations in different geographic regions of Illinois with different percentages of wetlands in their watersheds were analyzed to assess the influence of wetlands on streamflow. The objective of the research was to determine if streamflow parameters were influenced by the percentage of wetlands in the watersheds. The streamflow parameters analyzed included three peakflow parameters (peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio), a floodflow parameter (floodflow volume to total precipitation ratio), and two low-flow parameters (flows at 95 and 99 percent exceedance probability, Q₉₅ and Q₉₉). Because of significant regional differences in physiography and hydrology in Illinois, the data were synthesized to evaluate if there were regional patterns in the relations. The stations were grouped into three regions, northern, central, and southern Illinois. Even though the regionalization reduces the number of stations for analysis, important observations were made based on this analysis. It is also reasonable to assume that wetland functions could change with changes in the seasons because of the associated changes in climate and land cover. Therefore variability of the influence of wetlands were evaluated for the different seasons.

The major conclusions of the study follow. It should be mentioned that for the sake of brevity, the conclusions for peakflow were made on the basis of the results for peakflow to average precipitation ratio only. Even though the patterns are similar, the peakflow to average precipitation parameter showed the most consistent result among the three peakflow ratios. The conclusions for low flow were made on the basis of the results for Q₉₅, since the total number of zero values associated with it was less than that with Q₉₉.

1. Peakflow decreases as the percentage of wetland areas increases in the watershed. For the state as a whole, including the 30 stations, the peakflow parameter decreased by an

average of 3.7 percent for one percent increase in wetland area. The percent change in the peakflow parameter varied from a decrease of 8.7 percent for central Illinois to an increase of 1.5 percent in southern Illinois during the fall season. The influence of wetlands on peakflow is more pronounced in northern and central Illinois than in southern Illinois. Seasonally, wetland acreage influences peakflow more significantly in the fall season than the other seasons.

2. Floodflow volume decreases to a lesser extent as compared to peakflow, as wetland percentage increases. For the whole state, the floodflow volume parameter decreased by an average of 1.4 percent for one percent increase in wetland area. The percent change in the floodflow parameter varied from a decrease of 6.9 percent for northern and central Illinois to an increase of 4.4 percent in southern Illinois during the fall season. The influence of wetland acreage on floodflow volume is more pronounced in central and northern Illinois than in southern Illinois. Seasonally, wetland acreage influences floodflow volume more during fall than the other seasons.
3. Low flows increased with increasing wetland acreage in the watershed. For the whole state, the low-flow parameter increased by an average of 7.9 percent for one percent increase in wetland area. The percent change in the low-flow parameter varied from an increase of 22 percent in southern Illinois to a decrease of 4.7 in central Illinois during summer. The influence of wetland acreage on low flow is more pronounced in southern and northern Illinois than in central Illinois. Seasonally, the influence of wetland acreage on low flow is more significant during summer, fall, and winter and less significant during spring.

Limitations of the database should be remembered in generalizing the results of this study. The first limitation is the limited database used in the regional analysis: 11 stations for southern Illinois, 8 stations for central Illinois, and 11 stations for northern Illinois. For Illinois as a whole, data were for 30 stations. Therefore, results and conclusions for the whole state may be considered more definitive.

Another weakness of the database is the skewed distribution of wetland percentages in the watersheds analyzed. Although wetland percentage ranged from 0.2 to 13.7 percent, 11 watersheds (37 percent) had percentages of wetlands less than or equal to 2 percent, 19 watersheds (63 percent) had percentages of wetlands less than or equal to 5 percent, while 28 watersheds (93 percent) had percentages of wetlands less than or equal to 10 percent. Thus, a relatively uniform distribution of wetland percentage was not available. As a result, the conclusions drawn based on the study of these watersheds should be viewed with some caution until the range of percent wetland area is expanded.

The present analysis can be improved by increasing the number of stations for each region to at least 20. This will provide a broader database for each region and the regional and seasonal-regional conclusions will be more reliable. Attempts should also be made to select other watersheds in Illinois and from neighboring states so as to obtain a wider distribution of the percentage of wetlands in the watersheds. This will significantly improve both the scope and reliability of the conclusions from the current study.

REFERENCES

- Bailey, A.D., and T. Bree. 1980. *Effect of Improved Land Drainage of River Floodflows*. Institute of Civil Engineering. Flood Studies Report - Five Years on, London, England, pp. 95-106.
- Bardecki, M.J. 1987. *Cumulative Impacts of Agricultural Land Drainage on Watershed Hydrology*. Proceedings of the National Wetland Symposium: Wetland Hydrology, September 16-18, Chicago, IL. Editors, Jon A. Kusler and G. Brooks, pp. 124-128.
- Brunner, G.W. 1988. *Comparison of Modeling Techniques for Wetland Areas*. Report No. 88-4, The Hydrologic Engineering Center, USACOE, Davis, CA.
- Burke, W. 1968. *Drainage of Blanket Peat at Glenamony*. Proceedings of the Second International Peat Congress. H.M.S.O., 2:809-817, Edinburgh, Scotland.
- Campbell, K.L., and H.P. Johnson. 1975. *Hydrologic Simulation of Watersheds with Artificial Drainage*. Water Resources Research 11(1): 120-126.
- DeBoer, D.W., and H.P. Johnson. 1971. *Simulation of Runoff from Depression Characterized Watersheds*. Transactions of the American Society of Agricultural Engineers 14(4):615-620.
- Demissie, M., N.G. Bhowmik, and J.R. Adams. 1983. *Hydrology, Hydraulics, and Sediment Transport, Kankakee and Iroquois Rivers*. Illinois State Water Survey Report of Investigation 103, Champaign, IL.
- Eggelsmann, R. 1972. *The Water Balance of Low Land Areas in the Coastal Region of FRG*. Hydrology of Marsh Ridden Areas, UNESCO Press, Paris, France, pp. 355-367.

- Eli, R.N., and H.W. Rauch. 1982. *Fluvial Hydrology of Wetlands in Preston County, West Virginia*. Symposium on Wetlands of the Unglaciaded Appalachian Region. West Virginia University, Morgantown, WV, pp. 11-28.
- Haan, C.T., and H.P. Johnson. 1968. *Hydraulic Model of Runoff from Depressional Areas*. Transactions of the American Society of Agricultural Engineers 11:364-367, Ames, IA.
- Irwin, R.W., and H.R. Whiteley. 1983. *Effect of Land Drainage on Streamflow*. Canadian Water Resources Journal 8(2):88-103.
- Kloet, L. 1971. *Effects of Drainage on Runoff and Flooding within Pembina River Basins: North Dakota - Manitoba*. Bureau of Sport Fisheries and Wildlife, Bismarck, ND.
- McCubbin, G.A. 1938. *Agricultural Drainage in Southwestern Ontario - Its Effect on Stream Discharge*. Engineering Journal 21(2):66-70, Ontario, Canada.
- McGill, H.N., and A.C. Bennet. 1971. *Effects of Surface Drainage on Streamflow*. American Society of Agricultural Engineers, Paper 71-712.
- Moklyak, V.I., G.B. Kubyshkin, and G.N. Karkutsiev. 1972. *The Effects of Drainage Works on Streamflow*. Hydrology of Marsh-Ridden Areas, UNESCO Press, Paris, France, pp. 439-446.
- Moore, I.D., and C.L. Larson. 1979. *Effects of Drainage Projects on Surface Runoff from Small Depressional Watersheds in the North Central Region*, Water Resources Research Center, Bulletin 99, University of Minnesota, Minneapolis, MN.

Novitzki, R.P. 1982. *Hydrology of Wisconsin's Wetlands*. Information Circular 90, U.S. Geological Survey, Madison, WI.

Ogawa, H., and J.W. Male. 1983. *The Flood Mitigation Potential of Inland Wetlands*. Water Resources Research Center Report 138, University of Massachusetts, Amherst.

O'Kelly, J.J. 1955. *The Employment of Unit Hydrographs to Determine the Flows of Irish Arterial Drainage Channels*. Proceedings of the Institute of Civil Engineers 4:365-444, London, England.

Prior, C.H., and J.H. Hess. 1961. *Floods in Minnesota, Magnitude and Frequency*. Minnesota Department of Conservation, Division of Waters Bulletin No. 12.

Skaggs, R.W., and R.G. Broadhead. 1982. *Drainage Strategies and Peak Floodflows*. Summer Meeting of the American Society of Agricultural Engineers at University of Wisconsin, Madison, WI, June 27-30, 1982, Paper No. 82-2054.

DRAFT

DPL should be included in this
10/1/93

AN UNIFIED, COMPREHENSIVE APPROACH TO RECOVERY AND MANAGEMENT OF THE AREAS IMPACTED BY AND CONTRIBUTING TO THE GREAT FLOOD OF '93

DOI, CEA, USDA, FEMA and EPA (OPPE/OWOW/OFA) comments incorporated and redlined

I. VALUE OF NEPA APPROACH. A programmatic environmental impact statement (PEIS) that ends with definitive commitments and actions and/or legislative proposals is proposed. The value of the National Environmental Policy Act (NEPA) approach is that it is a recognized and understood institution for pursuing intergovernmental participation and problem solving. It is flexible, allows for and encourages public participation but does not trigger the Federal Advisory Committee Act requirements, and, finally, has established regulations that will ensure that all alternatives will be examined.

II. PURPOSE, OBJECTIVES, AND SCOPE. In the short-term, the national priority is to deliver a rapid and effective response to the flooding that places a priority on minimizing risks to life and property and on helping people in the region rebuild their lives and their communities. The purpose of this PEIS is to develop an overall strategy for flood recovery that embodies sustainable development by emphasizing floodplain management and ecosystem restoration. However, it is recognized that because many recovery programs are well underway, some of the PEIS recommended actions may occur too late to assist the current recovery efforts. Nevertheless, other foreseeable outcomes of the PEIS guiding minimization of floodplain damage susceptibility, watershed planning, etc., are likely to be applicable in the long-term.

Purpose, Need and Goals. The floodplains and watersheds of the Upper Mississippi and Missouri Rivers, and their tributaries are an extraordinary area, supporting substantial development and commerce and great ecological wealth. Yet as demonstrated by the Great Flood of '93, it is the source of enormous losses in life, property and natural resources due to flooding under existing management processes. Current policies have exacerbated increase damage from flooding by maintaining incentives for unwise development and need to be reconsidered. In the long-term, the Great Flood offers a profoundly important opportunity to review and improve the collective efforts of federal, state, and local governments and the private sector in managing the extraordinary resources and future potential of these watersheds. The PEIS will build upon the findings and recommendations of the Unified National Program for Floodplain Management, which was a multi-agency framework transmitted by the President to Congress.

This PEIS will serve as the vehicle to bring the federal agencies together with state and local resource, planning and regulatory agencies, tribal governments, potential project sponsors, and the public to develop a unified comprehensive approach to long-term recovery and subsequent management and improvement of the greater Upper Mississippi River, Missouri River, and their tributaries' floodplains affected by the Great Flood of '93. The PEIS will

DRAFT

10/1/93

address the current system of federal policies, practices and programs, and will develop options, where deemed appropriate, to revise policies and programs through legislative means or changes within agency purview. The PEIS's fundamental goal is to develop a set of comprehensive policy and programmatic options that reduces risks from flooding and emphasizes floodplain management that is compatible with sustainable development. Its aim is to unify federal, state, and local floodplain management policy and practices with other national goals (e.g., endangered species recovery; no-net loss of wetlands; swimmable, fishable and drinkable water; internalizing the costs of flood protection, etc.). It will also serve as a guide for developing, reviewing and/or setting priorities for site-specific options for recovery.

Objectives. The simultaneous objectives of this effort are to:

- Remove incentives for unsustainable development of floodplains;
- Reduce repeated flood loss damages and, thereby, reduce the risk to life, property, and environmental resources and reduce untenable financial risks represented by flood events;
- Restore the natural and beneficial functions and values of the greater Mississippi River area ecosystem including the floodplain, headwaters, groundwater, instream resources and upper watersheds as a primary means of reducing flood risks and flood damages;
- Establish a unified federal response to recovery and to coordinate responsibilities among federal, state, tribal and local agencies or entities; and,
- Establish a vehicle, that is sufficiently generic in nature for application to future disaster events or other geographic areas, to guide recovery efforts or guide implementation of floodplain management to avoid or minimize the effects of future flood-related disaster events.

Geographic Scope. The geographic scope would be those areas affected by or contributing to flooding along the Upper Mississippi River basin including the [lower] Missouri River and other tributaries.

Subject Scope. All federal, state, local and non-governmental activities affecting floodplain and its ecosystems' management would be encompassed by this effort. These would include (1) technical issues relating to the hydrology and ecology of the area, (2) programmatic issues involving a broad array of federal programs, (3) intergovernmental coordination issues, (4) economic issues relating to design of a comprehensive flood protection strategy

and maintaining proper incentives for floodplain management; and, (5) ecosystem restoration options.

III. FEDERAL AND STATE PARTICIPATION. The three agencies -- USDA, COE, FEMA, and DOI -- most involved with the Great Flood of '93 recovery effort which also have floodplain management expertise would be co-leads for the effort. Because NEPA allows designation of federal, state, and local governments as cooperating agencies, a suite of cooperating agencies is proposed. The cooperating agencies would be those federal agencies involved with the response and issues of floodplain and ecosystem management and environmental restoration and the states in which the federal disaster was declared, in association with this flood event, and that are interested in participating in this effort. Cooperating agencies' responsibilities would include assisting the development and completion of the study by identifying issues, data requirements, concerns and alternative solutions; developing and implementing baseline and impact studies; preparing draft text for the PEIS; reviewing pre-drafts of the document; preparing responses to comments, and, other tasks necessary for expeditious execution of this effort. The proposed cooperating agencies are: HUD, DOT, EPA, DOC, DOL and up to nine affected states.

IV. MANAGEMENT (see attached diagrammatic). The OMB/OEP Steering Committee will provide guidance on the purpose and need for the study, its objectives and goals, its scope of analysis, and the principles to be used in conducting the analysis. It will track progress, resolve issues elevated to its attention, review the findings and recommendations of the study, and coordinate development of the required decisions that would then be documented in agency-specific Records of Decision. Executive, Operations and Administrative Managers are proposed to direct activities to assure a legally defensible EIS treating the stated purpose and contemplated scope is prepared in a timely manner. In addition other key management and support personnel are proposed: Public Coordination Officer, Legal Counsel, and a Secretary.

The Floodplain Management Alternatives Committee, the nexus for organizing and managing the PEIS effort, would be limited in size to keep the group manageable to the co-leads and those federal cooperating agencies expected to bear the responsibility of undertaking the PEIS. This group will provide the day-to-day study management that will result in preparation of the PEIS. This group, therefore, is responsible for initiating and conducting public scoping, coordination, and outreach; formulation of alternatives; information gathering, data analysis and impact assessment activities; environmental statute compliance; and, all other activities necessary to complete a programmatic level of analysis in an environmental impact statement. Ideally the members of this committee will be comfortable with innovative and flexible approaches to problem solving; familiar with the spirit and statutory requirements of NEPA; managers within their agency with knowledge of their agency's priorities, policies and programs; and, have multiple agency experience or

DRAFT

10/1/93

knowledge associated with floodplain loss reduction, floodplain management, and/or emergency response and recovery authorities.

To accomplish a programmatic study of this broad nature and multiple purpose, four interagency teams are proposed to focus upon the most significant issues: 1) Flood Damage Susceptibility Team, 2) River Flows Management Team, 3) Floodplain Values and Ecosystem Restoration Team, and 4) Flood Response and Recovery Team. Cooperating agencies and other interested federal agencies could be participants on each team. Each team would be responsible for formulating the issues; developing options to address the issues; and, identifying the studies necessary to develop baseline and impact data. These options would be provided to the Floodplain Management Alternatives Committee for packaging into an array of alternatives that sharply define the issues. The teams would then be responsible for implementing the studies and analyses upon the direction of the Floodplain Management Alternatives Committee. A liaison to coordinate between the teams is also suggested to ensure consistency (e.g., of baseline assumptions and data sources), share information on activities of other teams, and identify potential problems between the teams. While consensus of team members is desirable, it is not necessary as the team will be responsible for developing issues and making recommending options for selection by the co-lead agencies in consultation with the cooperating agencies.

The Flood Damage Susceptibility Team, chaired by FEMA, would focus on strategies affecting land use within the floodplain and susceptibility to flood damage and disruption. For example, it would address such issues and tasks as:

- state and local floodplain regulations, zoning and building codes, development policies;
- establishing the true long-term financial costs associated with current operations along the river (e.g., crop subsidies, insurance, repetitive flood fight and repair costs, transportation costs);
- reducing long-term risks in the region through improved site-specific and programmatic master planning;
- improving environmental quality in the region and local communities through a more efficient menu of risk reduction options;
- programs to encourage stronger local government commitments on floodplain management;
- siting and design of federal, state, and local government and other publicly-owned or sponsored facilities with natural flood control and non-structural flood risk minimization measures;
- nonstructural means to provide protection or compensation for properties protected by levees ineligible for federal assistance.
- relocation of floodplain structures through new and existing incentive programs;
- flood proofing floodplain dependent public facilities structures or removing/treating/closing existing toxic/hazardous sites or solid waste landfills);

DRAFT

10/1/93

- moving businesses and residences to higher grounds (relocation programs);
- flood proofing residences and businesses;
- coordinating a federal position on land use, farming, crop subsidies, etc. in areas between federal levees;
- providing additional storm water retention ponds in urbanized and sub-urbanized areas to assist addressing non-point source water quality issues and asynchronization of flood peaks;
- utilization of, targeting and coordination of federal, state, tribal, and local programs that would assist floodplain management and flood loss reduction;
- identification of federal, state, tribal, and local programs and practices that work at cross-purposes to, or could better facilitate or recognize flood loss reduction and floodplain management goals;
- sewage treatment plant siting, construction and enhancement priorities and opportunities; moved
- evaluation of how the capacity and functioning of the natural river system to absorb floods is impacted by the location and amount of manmade flood control structures and land-use within the watershed;
- identifying how the land-use within the watershed has changed over time and what are the physical relationships to flooding and flood absorption capacity;
- evaluation of the economic and environmental benefits of relocating or removing levees in relatively unpopulated areas and creating wetlands, greenways, scenic rivers, trails, heritage corridors, ecological corridors, parks and other open spaces in order to help relieve the pressure of flood waters on built-up areas;
- evaluation of the relationships between increasing and decreasing flood protection in cropland areas versus downstream urban areas; and
- identification of floodwater reduction actions that could be taken under existing program provided additional funding is secured or other wise prioritized.

The River Flows Management Team, chaired by the COE, would focus on strategies affecting the risk of undesirable flooding and balancing multiple flow requirements. It would address such issues as:

- flood flows control;
- drought flows response;
- endangered, threatened species recovery flows;
- navigation flows;
- determining whether the existing system of levees and other flood control measures on the upper river systems is preventing small floods, but increasing the likelihood and severity of large floods by intensifying the height and velocity of flood waters;
- alternative levee design and construction methods;
- strengthening and reinforcing levees and dikes in urban and industrial areas; and,

- developing guidance on scope and alternatives analysis for new levee proposals prepared or reviewed by federal agencies (including a consistent framework for all Clean Water Act Section 404 analyses).

The Floodplain Values and Ecosystem Restoration Team, chaired by DOI and/or EPA, would address strategies affecting restoration of the ecological and beneficial values of the riverine ecosystems and floodplains. It would address such issues as:

- preparing an inventory of environmental opportunities and sensitive environments;
- setting priorities for environmental opportunities;
- identifying priority areas for innovative solutions to flood loss damage minimization (e.g. purchase of lands and easements, land exchanges, nonstructural solutions, etc.);
- federal, state and local acquisition of wetlands to reduce flood risk and assure continued wetland functions;
- developing a framework for matching best options for flood loss reduction with environmental opportunities;
- identifying areas suitable for greenways (floodways in urban and rural areas that serve recreation and other natural and beneficial uses);
- actions to recover federal or state listed endangered or threatened species or other special status species;
- upstream actions that reduce the rate of inflow from the watershed (e.g., restoration of wetlands, improved soil and water retention practices);
- using wetlands as natural flood retention basins and/or constructed wetlands for effluent polishing;
- actions to improve aquatic, riparian and floodplain habitat values;
- developing guidelines or requirements that runoff and flood storage capacity be built into projects qualifying for public assistance and/or federal or state permits or licenses;
- utilization of, targeting and coordination of federal, state, tribal, and local programs that would assist floodplain management and flood loss reduction;
- identification of federal, state, tribal, and local programs and practices that work at cross-purposes to, or could better facilitate or recognize flood loss reduction and floodplain management goals; and,
- identifying areas suitable for agriculture production and levels of protection for crop production;

The Flood Response and Recovery Team, co-chaired by USDA and FEMA, would focus on strategies affecting flood damage response. It would address such issues as:

- developing policies that fully internalize the costs of flood protection;
- actions/policy changes that reduce overall taxpayer support of activities conducted in floodplains;
- coordinating agency recovery responsibilities;
- improved guidance for future disaster relief and recovery programs;

DRAFT

10/1/93

- putting flood loss damage and floodplain management incentive programs on an even footing with rebuild to pre-flood options;
- conducting benefit-cost analysis of alternatives for comprehensive flood management alternatives, including structures, wetlands restoration and other environmental initiatives and effects of market mechanisms for internalizing the cost of flood protection;
- estimating funding necessary to effectively implement options to levee repair;
- improved relief efforts to private landowners through greater choice of options to rebuilding to pre-flood condition;
- exploring increased funding and eligibility requirements for other non-structural options such as refuge expansion, conservation easements, wetland restoration, etc;
- exploring the need for additional federal and state legislation to coordinate authority for floodplain activities (e.g., a floodplain management act similar to the Coastal Zone Management Act) or multiple use/sustained yield management for interstate river systems (e.g., a program similar to the federal timber land policy); moved
- establishing a firm federal assistance eligibility policy that is consistent across agencies and states (e.g., levee eligibility, cost-sharing, and replacement cost vs. market valuation);
- solid and hazardous waste monitoring, management or removal;
- establishing policy on which federal assistance is an entitlement, if any; and,
- coordinating agency utilization of the Stafford Disaster Assistance Act Reserve program (use of reserve federal employees in recovery efforts).

V. PUBLIC OUTREACH AND COORDINATION. Public scoping would be the responsibility of the Public Coordination Officer, Operations Manager, and the Floodplain Management Alternatives Committee. Public involvement must be actively sought out and encouraged for this effort to be successful. Continued coordination with the public, interest groups and other stakeholders is obviously a crucial component of this endeavor and a Public Coordination Officer is proposed to organize, undertake, and otherwise coordinate these activities. Two distinct work groups are envisioned to allow a representative suite of individuals to provide feedback to the Committee on issues germane to the study and PEIS and to facilitate dissemination of information to the public as a whole throughout the process. The Public Scoping, Outreach and Coordination Work Group would be composed of representatives of local governments and community organizations, farming, environmental, developmental, recreational/sporting, navigation, industrial, etc. interests. The States Work Group would be composed of up to nine State Coordination Officers that were originally established when the flood disaster was federally declared. These representatives would be responsible for identifying state issues, providing information to/from their respective state elected officials and state agencies and, ideally, obtaining state support necessary for implementation of the proposed alternative and any proposed mitigation measures that fall within state or local jurisdiction. Meetings with both Work Groups would occur throughout the PEIS process and particularly at important junctures.

DRAFT

10/1/93

VI. TECHNICAL OVERSIGHT. An Economic Work Group would be composed of representatives of the federal agencies. This group would provide expert oversight and issue resolution regarding economic issues and financial risk reduction. It would provide for consistency of economic analyses and perform independent review of team and contractor products to assure a consistent and defensible approach to economic analyses and, therefore, the conclusions reached as part of the study and EIS. The Group would be chaired by OMB and CEA and other members would include analysts from DPC, OEP, USDA, FEMA, COE, EPA, DOI, DOT, HUD, DOC, DOL, and HHS. Similarly, the Office of Science, Technology and Policy would utilize its resources, those of the National Academy of Sciences, the USGS, the National Biological Survey (NBS), FEMA, EPA, COE, and USDA to establish a common scientific data set and definitions from which each Team and the EIS contractor can proceed with analysis, issue characterization and solution formulation. It will also provide independent guidance, oversight, issue resolution, and review of data, modeling, engineering, hydrology, and other environmental studies. This will facilitate consistency of scientific, technological and engineering analyses and allow for independent review of team and contractor products. Both Work Groups may consult with academics and non-governmental organizations as deemed necessary or desirable. Meetings would occur throughout the PEIS process and particularly at important junctures.

VII. SCHEDULE. It is anticipated that with full interagency support the PEIS process could be completed in ten (10) months. To meet this admittedly optimistic compressed time frame will require expeditious handling of issues, activities, mobilization of federal research laboratories, dedication of a large number of staff across multiple agencies, contractor assistance, and dedication of office space for the Managers, Committee and Team members. A rough breakdown of the actions with ideal start dates follows:

- Scoping (Sept 15 - Nov 15)
- Analysis/Modeling (Sept 15 - Dec 31)
- Draft PEIS preparation (Sept 15 - Feb 15 (Notice of Availability))
- Public Review (45 days, ends March 30)
- Final PEIS preparation (March 30 - May 15)
- Public Review (30 days, ends June 15)
- Record of Decision (June 15)

The most problematic portion of this schedule is the time involved with analysis and modeling efforts. This time frame has been severely compressed to allow for decision-making as early as possible to allow for summertime construction activities. However, because recovery efforts are not expected to cease while this study effort is ongoing, it may be worthwhile to expand this schedule to ensure that issues are adequately identified and alternatives fully explored.

VIII. FIRST STEPS. The first tasks, after establishing agency participation and staff assignments, would be to:

DRAFT

10/1/93

- establish common data set, definitions [Science and Technology Work Group];
- review of the National Assessment of Floodplain Management produced by the Interagency Task Force on Floodplain Management [TEAMS];
- review of Interagency Hazard Mitigation team Reports on this and other flood events [TEAMS];
- identify ongoing or proposed studies that would assist PEIS analyses [ALL]
- coordinate ongoing and proposed studies to eliminate overlap and combine purposes, where possible [ALL];
- match studies' schedules with those of the PEIS [AGENCIES]; and,
- review ongoing and proposed studies to determine if any information gaps exist, to establish priorities for data needs, and develop cost estimates for those studies [TEAMS, ALTERNATIVES COMMITTEE].

It is anticipated that a great many activities and studies that are ongoing or planned will be incorporated into the PEIS. However, additional costs will be incurred by the co-lead agencies and cooperating agencies.

Attachment

DRAFT

10/1/93

**AN UNIFIED APPROACH TO RECOVERY AND MANAGEMENT OF THE
MISSISSIPPI RIVER FLOODPLAIN IMPACTED BY THE GREAT FLOOD OF '93**

MANAGEMENT (see attached diagrammatic)

OMB/OEP Steering Committee

Function: The OMB/OEP Steering Committee will provide guidance on the purpose and need for the study, its objectives and goals, its scope of analysis, track progress, resolve issues elevated to its attention, review the findings and recommendations of the study, and coordinate development of the required decisions that would then be documented in agency-specific Records of Decision.

Executive Manager

Function: Executive oversight of the PEIS.

Product: A legally defensible draft and final EIS affecting change in federal policies affecting floodplain management, floodplain development, flood recovery and ecosystem restoration.

Tasks:

- Charge(s) to work groups
- Charge to floodplain management alternatives committee
- Charges to teams
- Overall management of EIS effort

Operations Manager

Function: Direction and supervision of daily operations supporting production of the PEIS.

Product: A legally defensible EIS on schedule affecting change in federal policies affecting floodplain management, floodplain development, flood recovery and ecosystem restoration.

Tasks:

- Formation, organization, and oversight of Floodplain Management Alternatives Committee
- Organization of flood options and analysis teams.
- Initiation of scoping
- Formation of and coordination with Public Outreach, State, Economic and Science Work Groups
- Obtaining contractor support; coordinate between contracts (if necessary)
- Coordination, management of Floodplain Management Alternatives Committee
- Coordination of Flood Options Teams
- Guidance on and approval of issues, alternatives, scope of NEPA analysis
- Identification of interim reports supporting EIS
- Development of draft EIS
- Organization of response to comments on draft EIS

Administrative Manager

Function: Provides administrative assistance to the Executive Manager and the Operational Manager

Product: Coordinated flow of information; timely and satisfactory contractor work products supporting a legally defensible EIS on schedule

Tasks:

- Obtain contractor support of EIS
- Manage contractor preparation of EIS
- Liaison between Teams
- Liaison between Work Groups and Alternatives Committee
- Taking, transcribing and distributing meeting minutes
- Auditable tracking of expenditures (staffing, resource, travel)
- Tracking task progress, assignments and due dates
- Management of files

Legal Counsel

Function: Provides legal advice related to compliance and interpretation of NEPA, other environmental statutes and statutes addressed within the scope of the PEIS. Product: A legally defensible EIS on schedule

Tasks: Provides and coordinates legal opinions related to issues associated with recovery from the Great Flood '93

Secretary

Function: Provides clerical and secretarial support to personnel working on the EIS.

Products: As Assigned.

Tasks: Filing, typing, photocopying, management and obtaining supplies, preparation of paperwork, etc.

Public Coordination Officer

Function: Assures continued coordination and exchange with the public, as a whole, and the public coordination work group, states' work group, and all the cooperating agencies throughout development of the EIS.

Products: Public, state, tribal understanding and support of the purpose, scope, and proposals contained in the draft EIS.

Tasks:

- Development of a balanced (representative of stakeholders/public) Public Work Group
- Management of the Public Scoping Outreach and Coordination Work Group
- Frequent meetings of Public Scoping Work group
- Coordination with press, elected officials, and public inquires
- Establishment of and liaison to the States' Work Group
- Liaison to cooperating state agencies

DRAFT

10/1/93

- Assistance with managing and developing presentations for public scoping and outreach meetings

Science and Technology Work Group

Function: Provides for consistency of scientific, technological and engineering analyses and performs independent review of team and contractor products

Product: A consistent and defensible approach to scientific, technological and engineering analyses and conclusions reached as part of the study and EIS

Task:

- Establish and distribute a common scientific data set (i.e., flow data, flood stages, flood frequencies, water quality, ground water, geomorphology, and other existing data) and definitions that each Team and the contractor can utilize in undertaking further analyses;
- Serve as arbitrator on team disputes regarding scientific, technical, and engineering issues; and,
- Consult with academics, non-governmental organizations as determined necessary and desirable.

Membership:

OSTP, Chair

NAS, FEMA, USGS, NBS, EPA, COE, USDA

Economic Work Group

Function: Provides for consistency of economic analyses and performs independent review of team and contractor products

Product: A consistent and defensible approach to economic analyses and conclusions reached as part of the study and EIS

Task:

- Provide a written framework for conducting economic analyses that will enable comparison of alternatives, identification of least-cost alternatives to the federal government, address broad issues of social costs and benefits, and link individual projects impacts to regional and programmatic issues.
- Resolves team disputes regarding economic issues
- Consult with academics, non-governmental organizations as determined necessary and desirable

Membership:

OMB/CEA, Chairs

DPC, OEP, USDA, FEMA, COE, EPA, DOI, DOT, HUD, DOC, DOL, HHS

DRAFT

10/1/93

Floodplain Management Alternatives Committee

Function: The nexus for undertaking a unified, fully coordinated plan for recovery and management of the flood impacted area. This group will provide the coordination and decision-making necessary resulting in preparation of the PEIS.

Products:

- A full range of reasonable alternatives to achieve the purpose and need for federal action and that sharply define the issues to be addressed
- Identification and management of studies needed to support alternatives and impact analysis
- Development of frameworks and guidelines for future decision-making
- A legally defensible draft and final EIS

Tasks:

- See products, above.
- Development and coordination (with and within) appropriate agencies of proposed policies, program changes, for analysis in the EIS
- Initiating and conducting public scoping
- Formulation of alternatives
- Information gathering, data analysis and impact assessment activities
- Environmental statute compliance
- All other activities necessary to complete a programmatic level of analysis in an environmental impact statement.

Teams

Function: Focus on issues identified in PEIS proposal and other issues as deemed relevant. Reports directly to Alternatives Committee.

Products: A legally defensible EIS affecting change in federal policies affecting floodplain management, floodplain development, and flood recovery.

Tasks:

- Definition of Team's scope of analysis
- Development of options
- Conduct studies to assist issue and solution(s) identification
- Recommendations for alternatives (compatible suites of options)
- Identification and provision of data/information for use by contractor to prepare affected environment and environmental impacts sections of EIS
- Identification and management of studies supporting alternatives impact analysis
- Review of contractor(s) work products
- Review of pre-draft, draft EIS
- Response to comments
- Review of pre-final and final EIS

Recommended Participants (by agency, subject expertise [NAMES NEED TO BE PROVIDED BY AGENCIES]):

Floodplain Susceptibility Team

FEMA, Chair - floodplain management, hazard mitigation, disaster assistance, flood insurance program, public assistance
EPA - risk assessment/policy
USDA - agricultural policy, crop insurance
Coast Guard - bridges, navigational aids
HUD - building locations/codes, Community Block Development Grants
DOC/NWS - weather/flood forecast/historic data
OMB - fiscal policy, priorities
SBA - loan policy, business relocation

Floodplain Management and Ecosystem Restoration Team

DOI, Chair (FWS/USGS/NBS/BIA) - endangered species, refuges, migratory waterfowl, water and ecological data collection, Indian issues
FEMA - floodplain management, outreach
EPA - water policy, watersheds, wetlands
COE - policy, Institute for Water Resources, levee policy
HUD - urban renewal
SCS - wetlands reserve program, levee policy

River Flows Management

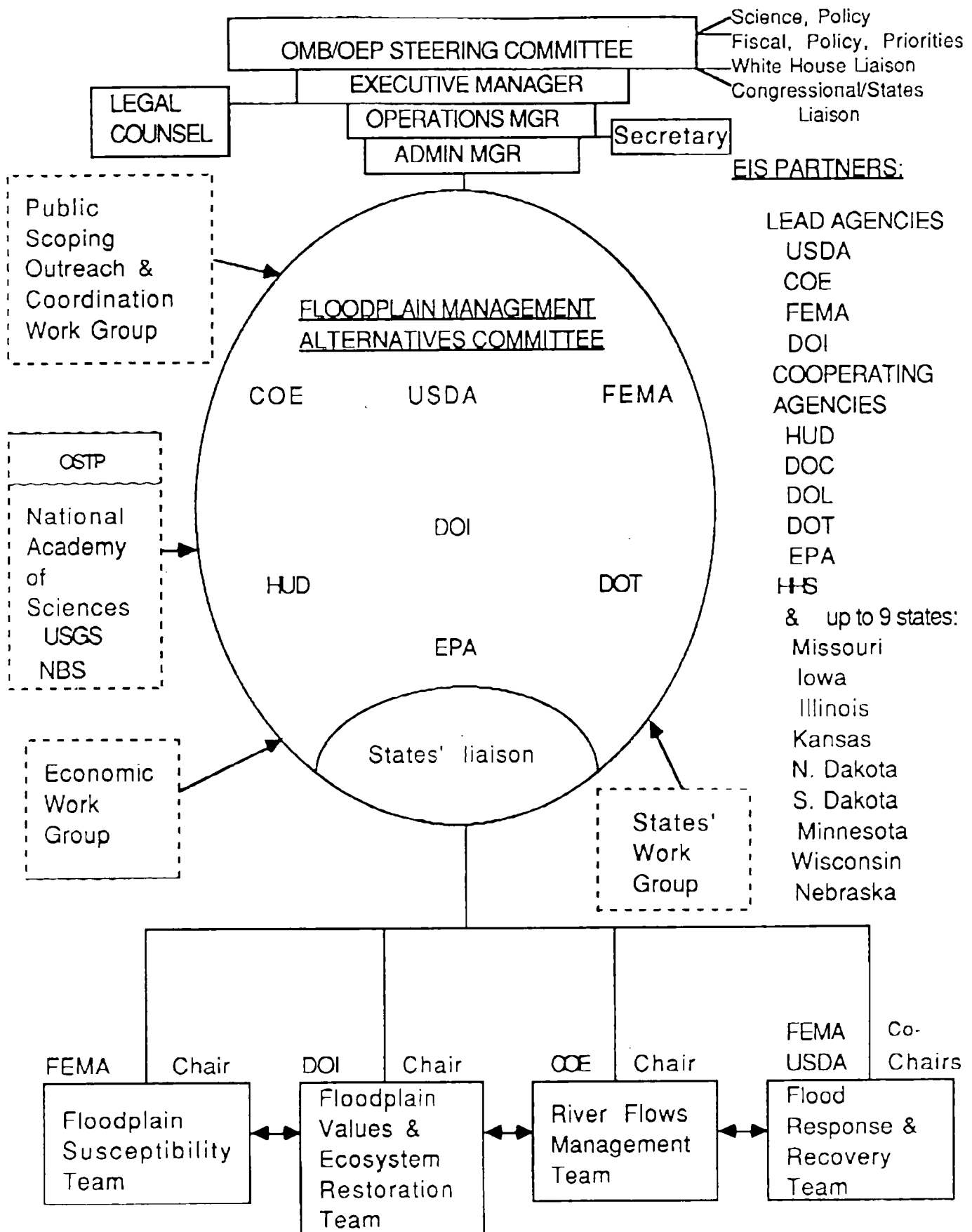
COE, Chair - water resources management, flood control, navigation, drought response
EPA - wetlands/CWA 404, water quality
FWS - endangered species flows
Coast Guard - navigation safety, bridges
USGS - flows data, hydrology
FEMA - floodplain management, risk reduction

Flood Response & Recovery Team

FEMA, Co-Chair - emergency response, recovery, hazard mitigation, floodplain management
USDA, Co-Chair - levees, crop insurance, foodstamp program
EPA - emergency response, water quality
DOI - levee alternatives
OMB - fiscal policy/priorities, economics
SBA - small business concerns
HHS/CDC - disease issues, public health
HUD - rebuilding, CBDG
EDA - economic development
COE - readiness, reconstruction, damage assessment
DOL - disaster unemployment assistance

(Attachment)

GREAT FLOOD OF '93 RECOVERY PEIS



October 7, 1993

Note to: Mark Schaeffer
Bob Stearns
Karl Otte
Will Stelle
Brian Burke
Michelle Altemus
Richard Sanderson
Ron Cogswell
Kevin Neyland

From:  Bruce Long

Attached is a draft study prepared for the Illinois Department of Conservation. It purports to establish the relationship between wetlands and streamflows. I am not qualified to pass on the validity of its conclusions, but believe that you should have the benefit of their thinking on this subject.

The study addresses a key technical issue in our thinking about future responses to flooding: whether a certain amount of wetlands can be reliably and economically substituted for levees and other flood control works.

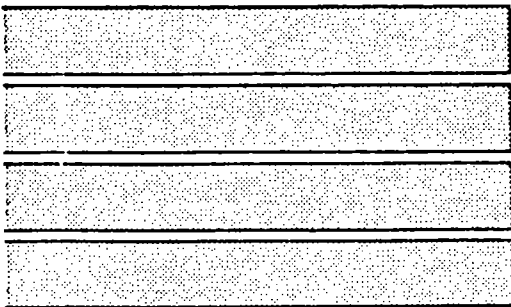
DRAFT

Influence of Wetlands on Streamflow in Illinois

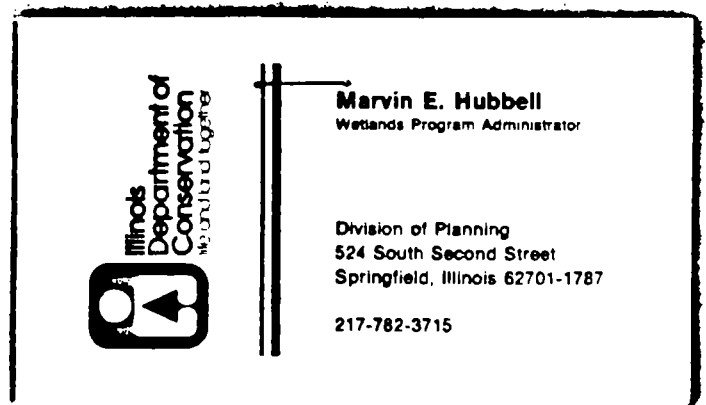
by Misganaw Demissie and Abdul Khan
Office of Sediment & Wetland Studies

Prepared for the
Illinois Department of Conservation

August 1993



Illinois State Water Survey
Hydrology Division
Champaign, Illinois



A Division of the Illinois Department of Energy and Natural Resources

DRAFT

INFLUENCE OF WETLANDS ON STREAMFLOW IN ILLINOIS

By
Misganaw Demissie and Abdul Khan

Prepared for the
Illinois Department of Conservation

Illinois State Water Survey
2204 Griffith Drive
Champaign, Illinois 61820-7495

August 1993

CONTENTS

	Page
Acknowledgments	ii
Tables	iii
Figures	iv
Abstract	vi
Introduction	1
Review of Literature.....	4
Data Analysis Methodology and Study Site Selection	7
Selection of Watersheds and Gaging Stations.....	7
Methods and Procedures.....	7
Flow Synthesis.....	7
Peakflow and Floodflow Volume.....	12
Low Flow.....	17
Evaluation Procedure.....	17
Testing Method.....	20
Results	23
Peakflow and Floodflow Volume.....	23
Statewide Analysis.....	23
Regional Analysis.....	28
Seasonal Analysis.....	30
Seasonal-Regional	38
Fall.....	38
Winter.....	39
Spring.....	39
Summer	40
Low Flow.....	41
Statewide Analysis.....	41
Regional Analysis.....	41
Seasonal Analysis.....	41
Seasonal-Regional	46
Fall.....	46
Winter.....	46
Spring.....	46
Summer	48
Summary and Conclusions.....	49
References.....	52

ACKNOWLEDGMENTS

This study was accomplished as part of the regular work of the Illinois State Water Survey. The research upon which this report is based was supported in part by funds provided by the Illinois Department of Conservation (IDOC). Marvin Hubbell was the project manger for IDOC and provided valuable guidance and coordination for the project. Radwan Al-Weshah, graduate research assistant at the Water Survey and Venkat Swaminathan and Charles Kemper, students at the University of Illinois, were helpful in processing the data and preparing many of the illustrations. Becky Howard typed the camera-ready copy of the report, Gail Taylor and Eva Kingston edited it, and Linda Hascall and David Cox prepared some of the illustrations.

TABLES

Page

1	Information on Streamflow Gaging Stations Used in the Study.....	
2	Regression Analysis Results and Percent Change for Statewide Analysis	
3	Regional Regression Coefficients and Percent Change Values for Peakflow and Floodflow Parameters.....	
4	Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Average Precipitation Ratio (Q_p/P_a) for a One Percent Change in Wetland Area	
5	Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Peak Precipitation (Q_p/P_p) for a One Percent Change in Wetland Area	
6	Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Total Precipitation (Q_p/P_t) for a One Percent Change in Wetland Area	
7	Influence of Wetlands on Floodflow Volume as Measured by the Percent Change in the Ratio of Floodflow Volume to Total Precipitation (V/P_t) for a One Percent Change in Wetland Area	
8	Regional Variability of Influence of Wetlands on Low Flow in Illinois as Measured by the Percent Change in Q_{95} and Q_{99}	
9	Seasonal Variability of Influence of Wetlands on Low Flow in Illinois as Measured by the Percent Change in Q_{95} and Q_{99}	
10	Seasonal Variability of Influence of Wetlands on Low Flow by Region in Illinois as Measured by the Percent Change in Q_{95} and Q_{99}	

FIGURES

		Page
1	Locations of selected drainage basins, streamgaging stations, and precipitation stations.....	
2	Frequency distribution of drainage areas of selected watersheds	
3	Frequency distribution of wetland percentages in selected watersheds	
4	Frequency distribution of storm values of peakflow to average precipitation ratio for three selected stations.....	
5	Frequency distribution of storm values of peakflow to peak precipitation ratio for three selected stations.....	
6	Frequency distribution of storm values of peakflow to total precipitation ratio for three selected stations.....	
7	Frequency distribution of storm values of floodflow volume to total precipitation ratio for three selected stations.....	
8	Determination of flows at different exceedance probabilities.....	
9	Percent change (PC) determination from regression parameters	
10	Relation between peakflow to average precipitation ratio and percent wetland for Illinois	
11	Relation between peakflow to peak precipitation ratio and percent wetland for Illinois	
12	Relation between peakflow to total precipitation ratio and percent wetland for Illinois	
13	Relation between floodflow volume to total precipitation ratio and percent wetland for Illinois	
14	Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland	
15	Seasonal variation of the relations between peakflow and floodflow volume parameters and percent wetland	

FIGURES (concluded)

- 16 Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for fall
- 17 Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for winter
- 18 Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for spring.....
- 19 Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for summer
- 20 Relation between low-flow parameter, Q_{95} , and percent wetland for Illinois
- 21 Relation between low-flow parameter, Q_{99} , and percent wetland for Illinois
- 22 Seasonal variation of the relation between parameters Q_{95} and Q_{99} and percent wetland low flow.....

ABSTRACT

One of the major functions of wetlands is to store water and release it gradually to surface and ground-water bodies. It is generally assumed that wetlands reduce flooding, increase low flows, and serve as recharge areas for ground water. However, there have not been systematic studies to quantify the influence of wetlands on flooding and low flows. This research was initiated to investigate the hydrologic functions of wetlands in Illinois based on available streamflow records. The research was designed to answer the more general question, "how does the presence or absence of variable size wetlands in a watershed influence streamflow?"

Streamflow records from 30 gaging stations monitoring watersheds with variable wetland areas were analyzed to assess the influence of wetlands on streamflow. The main objective of the analysis was to determine if streamflow parameters of streams draining watersheds with varying percentage of wetland areas were related to the percentage of wetlands in the watersheds. The streamflow parameters analyzed included peakflow, floodflow volume, and low flow. From the results of this analysis, in general, it can be concluded that peakflow and floodflow volume decrease, and low flows increase with increasing percentage of wetlands in the watershed. The influence of wetlands was more noticeable on peakflow and low flow than on floodflow volume. For all the gaging stations analyzed, the peakflow to average precipitation ratio decreased on the average by 3.7 percent, floodflow volume to total precipitation ratio decreased by 1.4 percent, and low flow (represented by Q_{95}) increased by 7.9 percent for an increase of one percent wetland area in a watershed. There were, however, significant regional and seasonal differences in the rate of change.

Regionally, wetland influence was more noticeable in central and northern Illinois than in southern Illinois for both peakflow and floodflow volume. The influence of wetlands on low flow was more noticeable in southern and northern Illinois than in central Illinois, however. The peakflow to average precipitation ratio decreased by 5.9 to 7.9

percent, while floodflow volume to total precipitation ratio decreased by 4.5 and 2.3 percent in central and northern Illinois, respectively. For low flow, Q95 increased by 15.9 and 15.0 percent in southern and northern Illinois, respectively.

Seasonally, for the state as a whole, wetland influence was the most prominent in fall for the peakflow to average precipitation ratio (5.7 percent decrease) and in summer for the floodflow volume to total precipitation ratio (3.1 percent decrease). For low flow, the influence of wetlands was equally noticeable in fall (8.4 percent increase in Q95) and summer (8.0 percent increase in Q95).

INFLUENCE OF WETLANDS ON STREAMFLOW IN ILLINOIS

by
Misganaw Demissie and Abdul Khan
Office of Sediment & Wetland Studies
Illinois State Water Survey
Champaign, Illinois

INTRODUCTION

The objective of this project was to assess the influence of wetland acreage on streamflow by analyzing existing streamflow records in Illinois. Analysis of streamflow records for streams with various ratios of wetlands in their watersheds may provide information on how wetlands influence the hydrology of the watershed. If streams draining watersheds with different percentages of wetland area to total drainage area have different hydrologic responses, then general relationships can be developed between percentages of wetland and streamflow parameters. These relationships can then be used to evaluate wetland functions and impacts of land-use practices that affect wetland acreage.

There are four major mechanisms by which wetlands can influence streamflows: runoff generation, flow retardation due to increased flow resistance, storage, and low-flow augmentation. Runoff generation is linked to wetlands' soil moisture and land-cover conditions, important parameters that greatly influence how much runoff is generated from various rainfall events. For example, if an area is already saturated from antecedent rainfall, even small precipitation amounts can produce large surface runoff. On the other hand, if an area is dry, large precipitation amounts may produce little or no runoff as most of the precipitation infiltrates into the ground. An area with dense vegetation will intercept more incoming rainwater than an area with little or no vegetative cover. As a result, surface runoff from the former will be much less than that from the latter. In

contrast, delayed flow from an area with dense vegetation will be greater than from an area with less vegetative cover.

The presence of wetland vegetation in the watershed and along drainage channels will increase flow resistance over land and in the streamchannels resulting in slow delivery of runoff from upstream to the streamchannel. When a flood event occurs along a stream in a watershed with wetlands along the streambanks, the streamflow increases and eventually overflows the banks. The water then has to flow through the adjoining wetlands, which significantly increases the resistance to flow. Since wetlands typically support a large amount of vegetation, the resistance to overbank flow is greater for a stream adjoining a wetland than for a stream not adjoining a wetland. As a result, a significant difference will exist between the flow characteristics of a stream adjacent to a wetland and one not adjoining a wetland.

Another major influence that wetlands exert on streamflow is the flood storage capacity they provide. Since most wetlands are located in depressions and poorly drained areas, they provide significant storage potential. By storing runoff from adjoining areas, wetlands retard or reduce the amount of runoff that reaches streamchannels. Therefore depending on initial conditions, wetland areas could significantly affect the streamflow.

The presence of wetlands in a watershed may also result in low-flow augmentation in streams. In wetland areas, water stored in surficial depressions and underground is gradually released to adjoining streams during periods of low flows. This generally results in higher low-flow conditions for streams that drain areas containing wetlands.

One of the parameters that can be used to characterize and distinguish watersheds containing different areas of wetlands is the ratio of wetland area to the total drainage area of the watershed. The major objective of this study, therefore, was to investigate streamflow records in Illinois and relate various streamflow parameters to the percentage of wetlands in the watershed. Although it is generally accepted that wetlands reduce streamflow peaks and increase low flows, this generalized concept may not always be true.

The hydrologic response of wetlands may vary depending on geographic location, storm intensity and duration, and season of the year. Because of significant regional and seasonal differences in Illinois, it is important to ascertain if the influence of wetlands varies between regions and by season. This research effort has attempted to address issues related to the regional and seasonal influence of wetlands on streamflow in Illinois. However, because of the small number of stations in the different regions, the regional analysis needs to include more stations in the analysis.

REVIEW OF LITERATURE

The role of wetlands on streamflow has been a subject of considerable debate. Past studies have served only to highlight this debate and the differing conclusions. Irwin and Whiteley (1983), Bardecki (1987), and Brunner (1988) have reviewed results from previous studies related to the influence of wetlands on streamflow.

McCubbin (1938) concluded that drainage activity did not have any impact on the peakflow values of the Grand River or the Thames River in Ontario, Canada. O'Kelly (1955), while investigating the influence of artificial drainage on flood hydrographs, found that the peakflow increased substantially after drainage. Prior and Hess (1961) performed flood frequency analysis for Minnesota and decided that flood magnitude was reduced with increasing percentage of marshes in the watershed. They assumed that a percentage of lakes represented the percentage of marshes in the watershed.

In a series of studies, Haan and Johnson (1968), DeBoer and Johnson (1969), and Campbell and Johnson (1975) used the Iowa State Model to examine the influence of wetland drainage on streamflow by using storm hydrograph simulations. They concluded that drainage usually increased the runoff volume irrespective of the rainfall intensity and duration. For high-intensity, short-duration rainfall, the peakflow values remain unchanged even with improved drainage, while for low-intensity, long-duration events, peakflows in general increased with increased drainage. Moore and Larson (1979), using an improved version of the Iowa State Model, called the Minnesota Model, reached essentially similar conclusions.

Burke (1968), in an investigation of two watersheds, one drained and the other undrained, found that peakflow was lower in the drained watershed than in the undrained watershed. Kloet (1971), in a similar study, reached exactly the opposite conclusion. McGill and Bennet (1971) studied the effect of drainage on runoff using a synthetic

hydrograph approach and concluded that drainage resulted in an insignificant reduction in peak discharge value.

Moklyak et al. (1972) investigated a drained and an undrained watershed, and concluded that drainage decreased both annual runoff and peakflow. Eggelsmann (1972) investigated two adjoining high water table peat watersheds, one undrained and the other drained by a tile drainage system. He found that while the runoff volumes from the two watersheds were similar, peakflows from the undrained peat basin were much greater (up to three times) after a rainfall event than those from the tile-drained watershed. Bailey and Bree (1980), in a study of 12 boggy watersheds, found that flood peaks were substantially increased as a result of drainage. Novitzki (1982) studied the influence of wetlands on streamflow in Wisconsin and concluded that flood peaks may be as much as 80 percent lower in basins with much lake and wetland area. Eli and Rauch (1982), in a study of two wetland watersheds in northern West Virginia, concluded that wetlands had little effect on peakflows or low flows of the studied watersheds. Skaggs and Broadhead (1982) studied the impact of drainage on runoff volume and peakflow using the model DRAINMOD. They concluded that subsurface tile drainage decreased the runoff volume and peakflow values.

Ogawa and Male (1983) studied the role of wetlands on streamflow in Massachusetts and found that peakflow increased with decreasing wetland percentage in the watershed. Demissie et al. (1983) studied the upper Kankakee and Iroquois Rivers in Illinois and Indiana. Significant wetlands were present along the upper Kankakee River and absent along the Iroquois River. They found that 50-year flood in the Iroquois River was almost twice of that in the upper Kankakee River for the same drainage area. On the other hand, the 7-day, 10-year low flow for the upper Kankakee River was more than ten times of that in the Iroquois River for the same drainage area.

It was mentioned previously that it is generally accepted that wetlands reduce streamflow peaks and increase low flows. This function of wetlands is attributed to their

ability to store floodwater during storm events for release later. However, this generalized concept may not always be true as illuminated by the review of literature of work done by researchers in the past. Depending on the extent of the wetland, its geographic location, storm intensities and durations, and seasons of the year, the influence of wetlands on streamflow may vary greatly with the region as well as the specific wetland type. As a result, it is imperative that these factors be given careful consideration when investigating the influence of wetlands on streamflow.

DATA ANALYSIS METHODOLOGY AND STUDY SITE SELECTION

In this section, the basis of selecting the watersheds and streamgaging stations for analysis will be outlined. The methods and procedures used will also be described.

Selection of Watersheds and Gaging Stations

Before analyzing streamflow records, it was necessary to exclude streams and watersheds that are significantly affected by known natural or man-made features. For example, streams greatly influenced by large rivers and lakes like the Mississippi and Ohio Rivers and Lake Michigan were excluded from analysis. All gaging stations located downstream of dams and major discharge points were also excluded. After considering these factors, 30 gaging stations were selected: 11 in southern Illinois, 8 in central Illinois, and 11 in northern Illinois. Table 1 lists the selected watersheds and the gaging stations, and figure 1 shows their locations. The drainage areas of the selected stations ranged from 7 to 1,282 square miles. The percentages of wetlands in these watersheds varied from a minimum of 0.2 percent to a maximum of 13.7 percent. The streamflow data for these watersheds were available for periods of at least ten years from 1979 to 1988. The frequency distributions of the watershed drainage areas and wetland percentages are provided in figures 2 and 3, respectively.

Methods and Procedures

Flow Synthesis

The analysis was conducted for a ten-year period from 1979 to 1988. This period was selected to closely correspond to the wetland area data that were determined from the National Wetland Inventory conducted in the early 1980s. Daily flow values for the ten-year period were obtained for each of the gaging stations. Three streamflow parameters were selected for analysis: peakflow, floodflow volume, and low flow. Daily precipitation

Table 1. Information on Streamflow Gaging Stations Used in the Study

<i>Streamflow station</i>	<i>ID number</i>	<i>Stream name</i>	<i>Drainage area (sq mi)</i>	<i>Wetland (percent)</i>	<i>Period of record</i>
03336645	1	Middle Fork Vermilion	428.00	1.34	1979-1988
03336900	2	Salt Fork River	131.10	0.22	1960-1988
03379500	3	Little Wabash	1118.90	1.06	1915-1988
03380500	4	Skillet Fork	457.83	4.04	1929-1988
03382100	5	South Fork Saline	145.10	9.29	1966-1988
03384450	6	Lusk Creek	42.40	0.47	1969-1988
05466500	7	Edwards River	440.30	1.08	1935-1988
05469000	8	Henderson Creek	430.30	0.82	1935-1988
05495500	9	Bear Creek	345.20	1.87	1944-1988
05532000	10	Addison Creek	22.90	0.76	1952-1988
05534500	11	North Branch Chicago	19.50	4.41	1953-1988
05536000	12	North Branch Chicago	98.10	3.52	1951-1988
05536275	13	Thorn Creek	102.90	8.64	1947-1988
05539900	14	West Branch DuPage	27.90	6.06	1961-1988
05540095	15	West Branch DuPage	92.30	7.53	1969-1988
05550500	16	Poplar Creek	35.50	7.28	1952-1988
05551700	17	Blackberry Creek	69.60	4.19	1961-1988
05568800	18	Indian Creek	62.20	0.47	1960-1988
05570370	19	Big Creek	40.70	8.43	1972-1988
05570380	20	Slug Run	7.10	13.68	1975-1988
05570910	21	Sangamon	237.70	0.80	1979-1988
05585000	22	La Moine	1281.80	2.27	1921-1988
05591200	23	Kaskaskia	468.90	0.87	1971-1988
05593520	24	Crooked Creek	251.60	5.80	1975-1988
05594450	25	Silver Creek	152.49	4.17	1967-1988
05594800	26	Silver Creek	460.75	5.64	1971-1988
05595200	27	Richland Creek	127.12	2.65	1970-1988
05595730	28	Rayse Creek	90.40	4.23	1979-1988
05597000	29	Big Muddy River	783.60	11.78	1915-1988
05597500	30	Crab Orchard	31.30	8.09	1952-1988

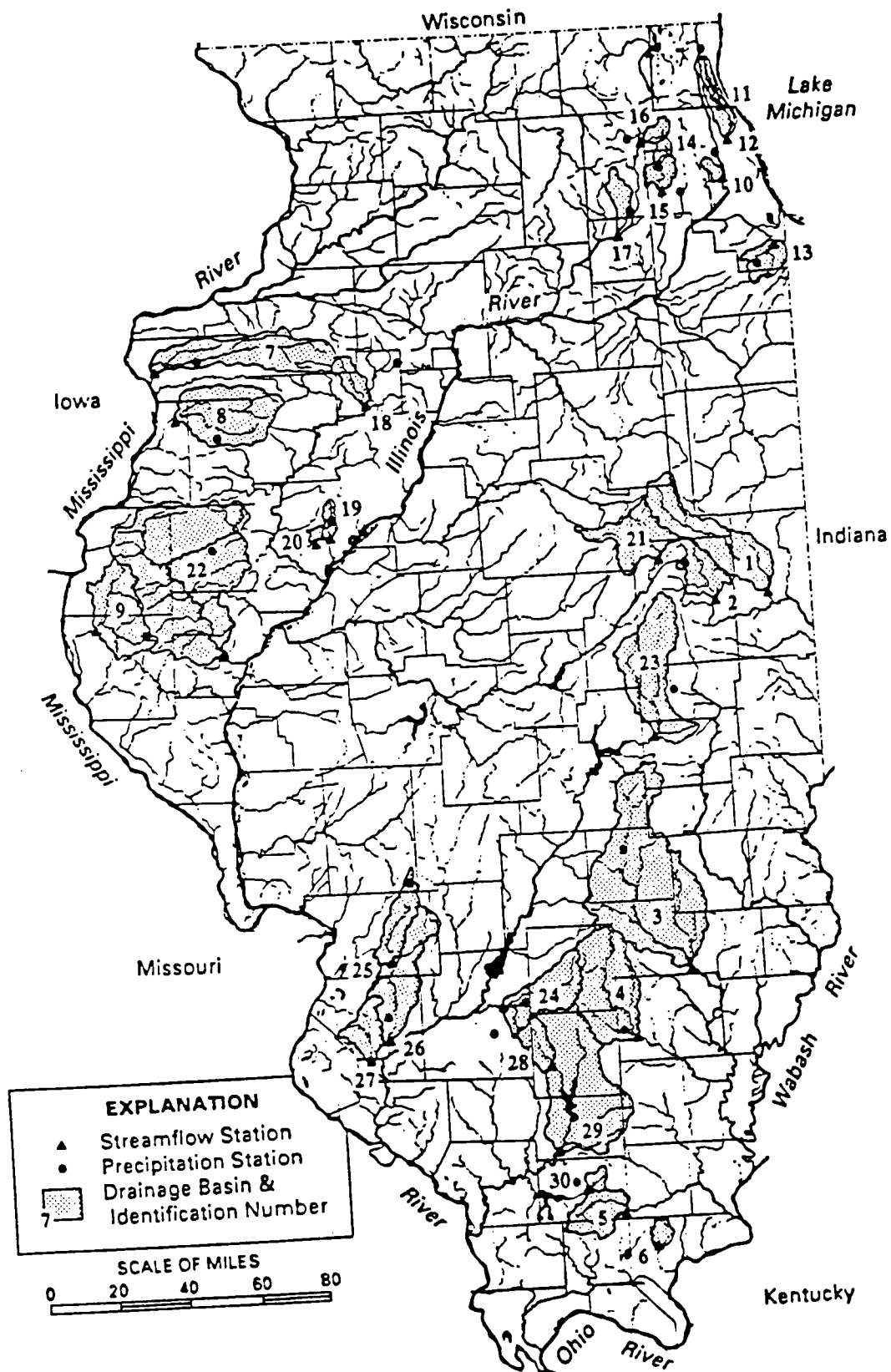


Figure 1. Locations of selected drainage basins, streamgaging stations, and precipitation stations

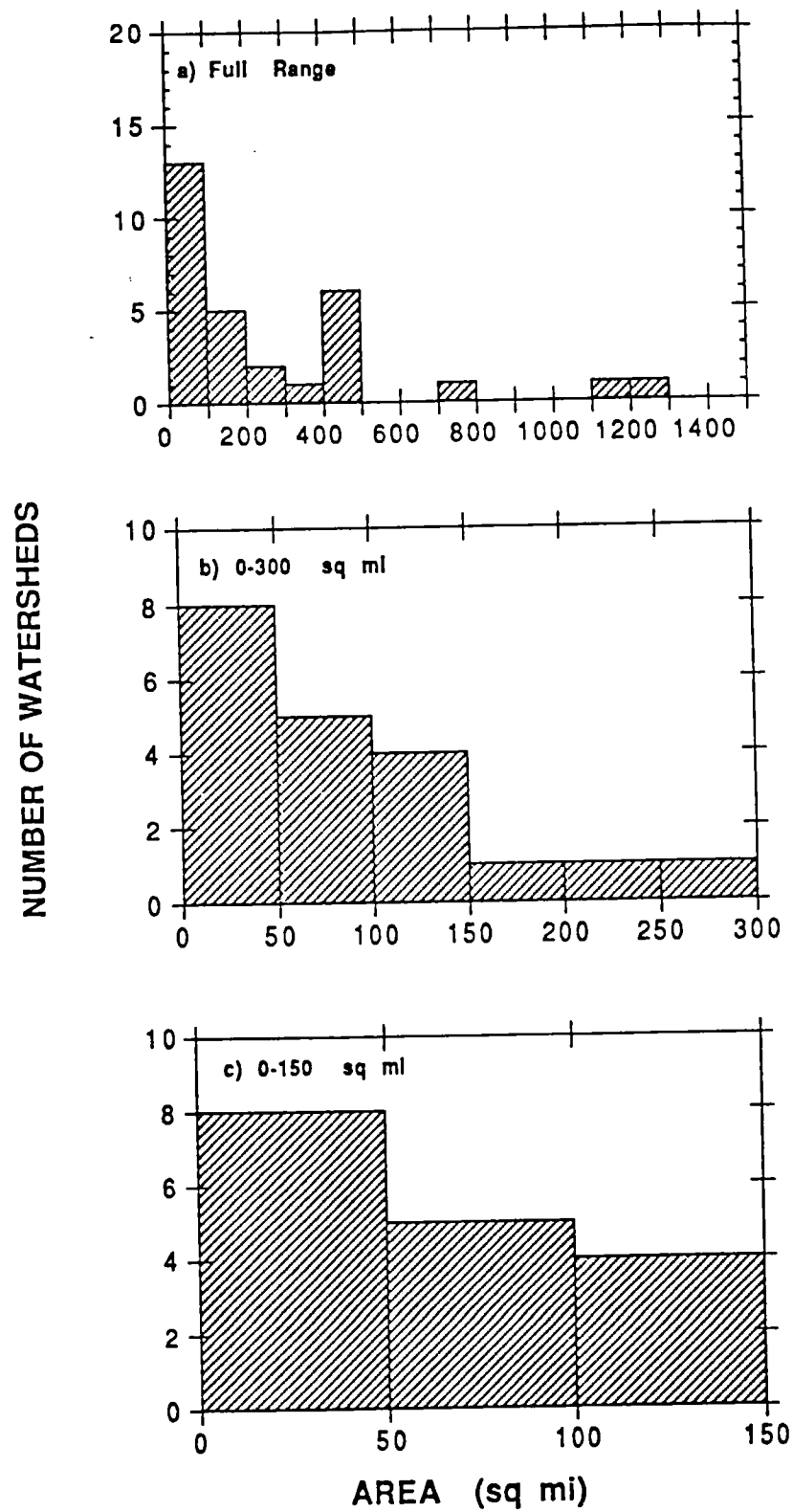


Figure 2. Frequency distribution of drainage areas of selected watersheds

NUMBER OF WATERSHEDS

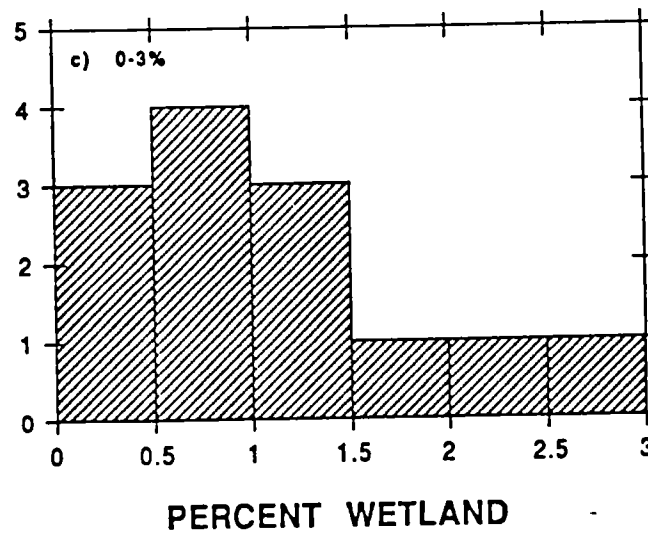
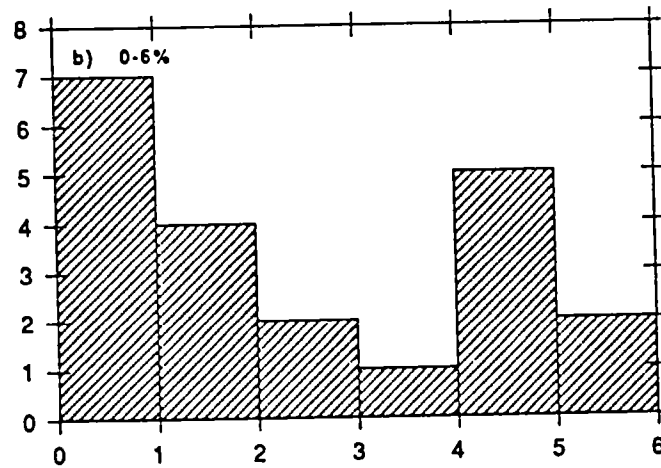
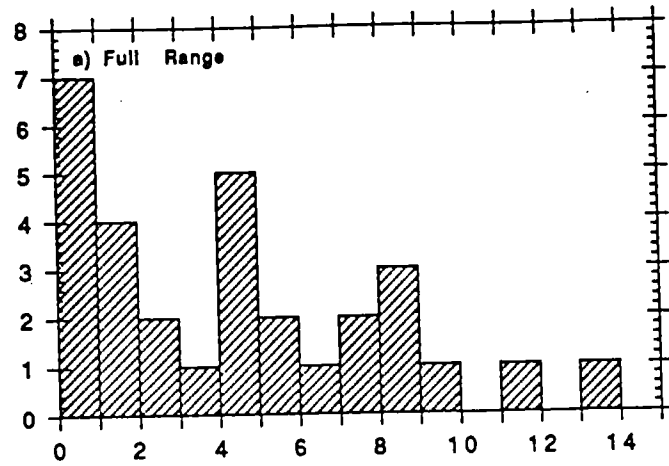


Figure 3. Frequency distribution of wetland percentages in selected watersheds

data from a station in the watershed for the same period were also obtained to normalize the streamflow.

Peakflow and Floodflow Volume. For peakflow and floodflow volume analyses, daily streamflow data for each year were examined and several flood events were selected. The peakflow values in cubic feet per second (cfs) were divided by drainage area and converted to inches per day. The corresponding volumes of the flood were also computed, and the seasons in which the floods occurred were identified. From the daily precipitation data, the average, peak, and total precipitation values associated with the selected flood events were determined. In order to remove the influence of the variability in precipitation from the analysis, four ratios were then calculated for each flood event to aid in the analysis: peakflow to average precipitation ratio; peakflow to peak precipitation ratio; peakflow to total precipitation ratio; and floodflow volume to total precipitation ratio.

For each station, the mean value for each normalized parameter was computed from the data for all the flood events. The frequency distribution of the individual values (used to compute the mean values) of the four parameters for Skillet Fork, Big Creek, and Crooked Creek are shown in figures 4-7. The distributions for the other stations were similar. The mean normalized parameters so computed were plotted against the corresponding percentages of wetlands for the watershed. The independent variable was the percentage of wetlands within each watershed. These values were generated by the Illinois Natural History Survey from the Illinois component of the National Wetland Inventory.

To investigate the regional influence on the peakflow and volume ratios, the mean normalized parameters were plotted by grouping the watersheds into three regions: south, central, and north. To investigate the seasonal influence of wetlands on streamflow, parameters were grouped on the basis of the four seasons. For each station, the mean parameters for each season were then plotted against their percentages of wetlands.

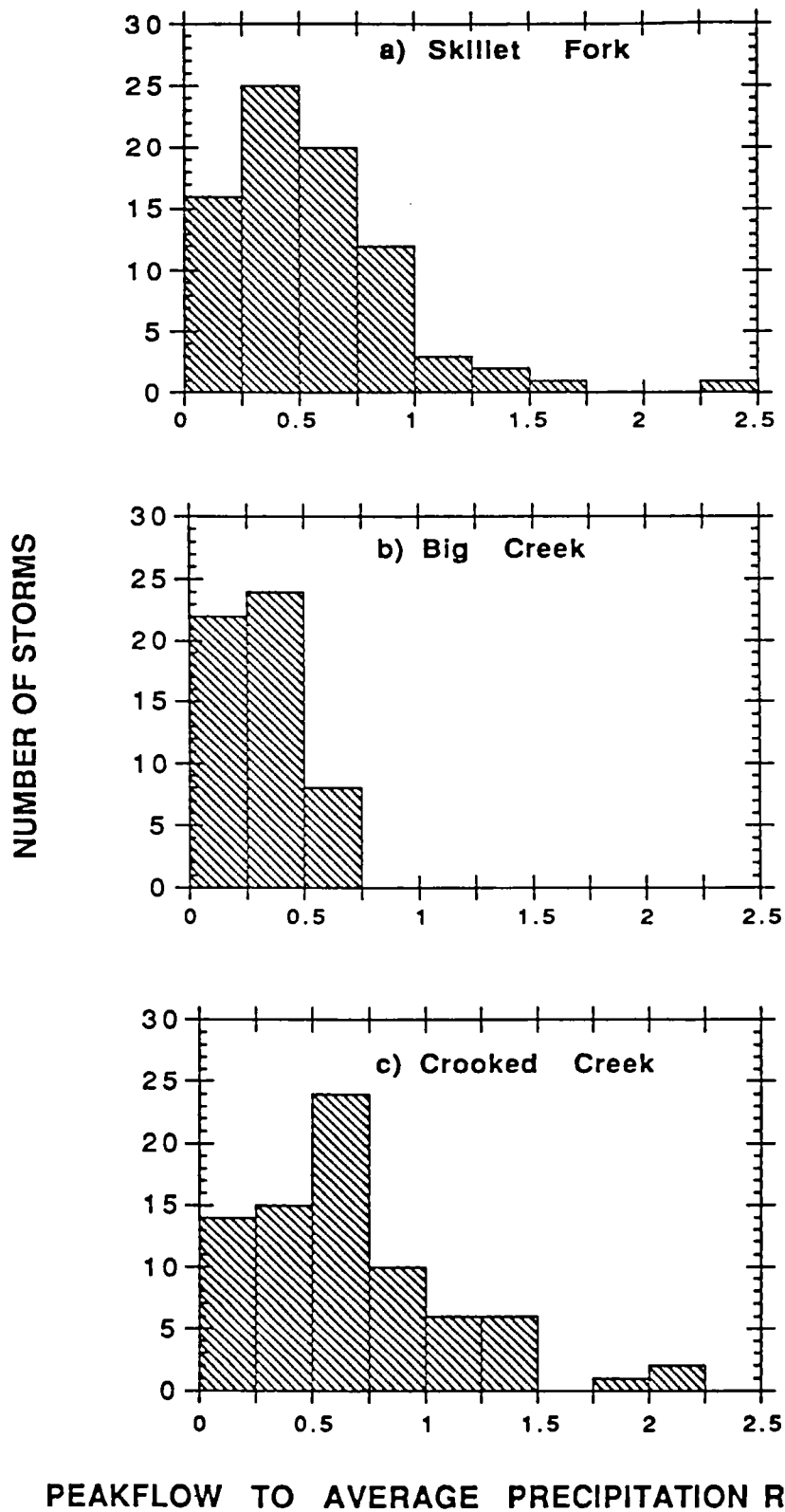


Figure 4. Frequency distribution of storm values of peakflow to average precipitation ratio for three selected stations

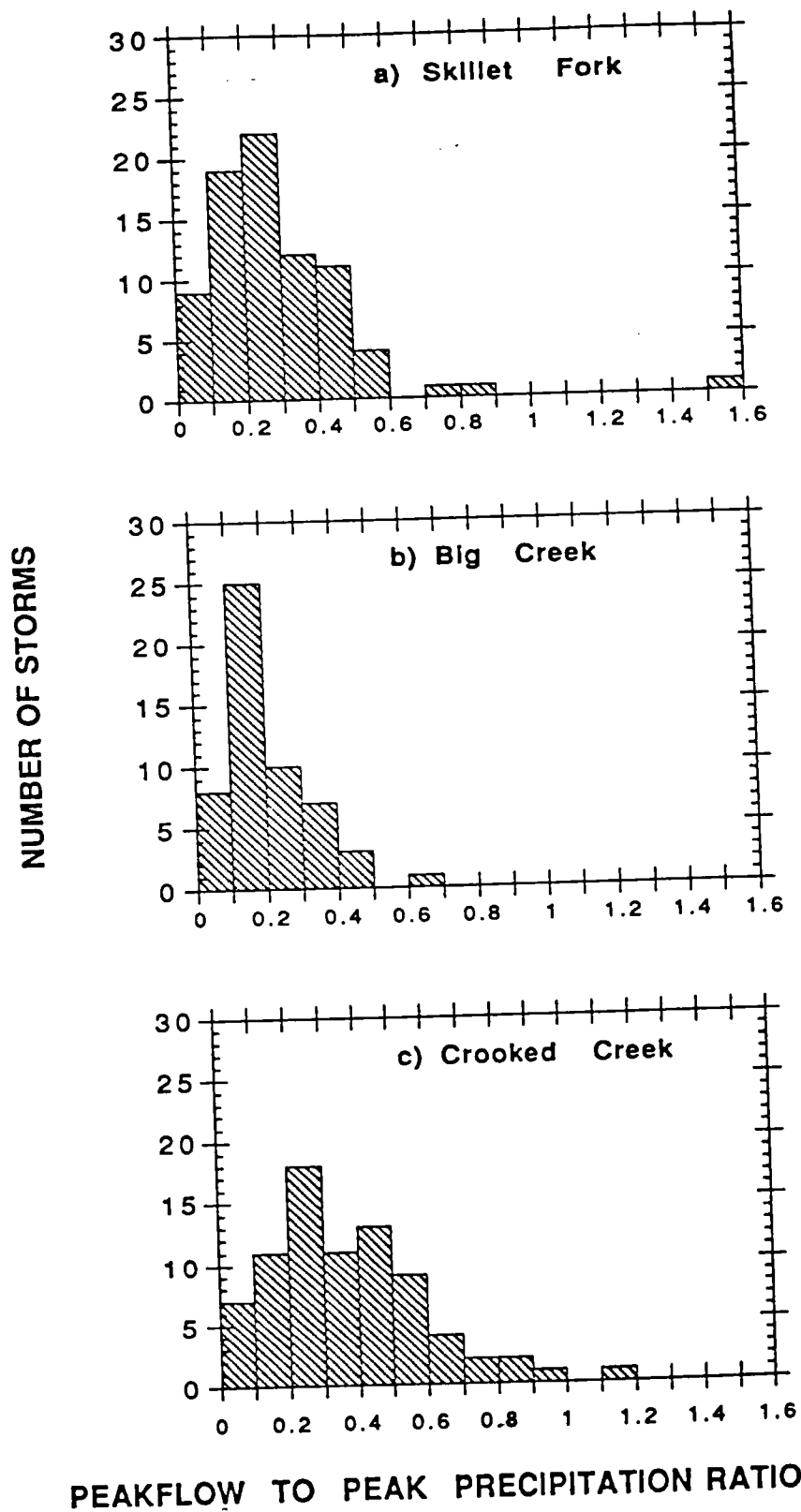


Figure 5. Frequency distribution of storm values of peakflow to peak precipitation ratio for three selected stations

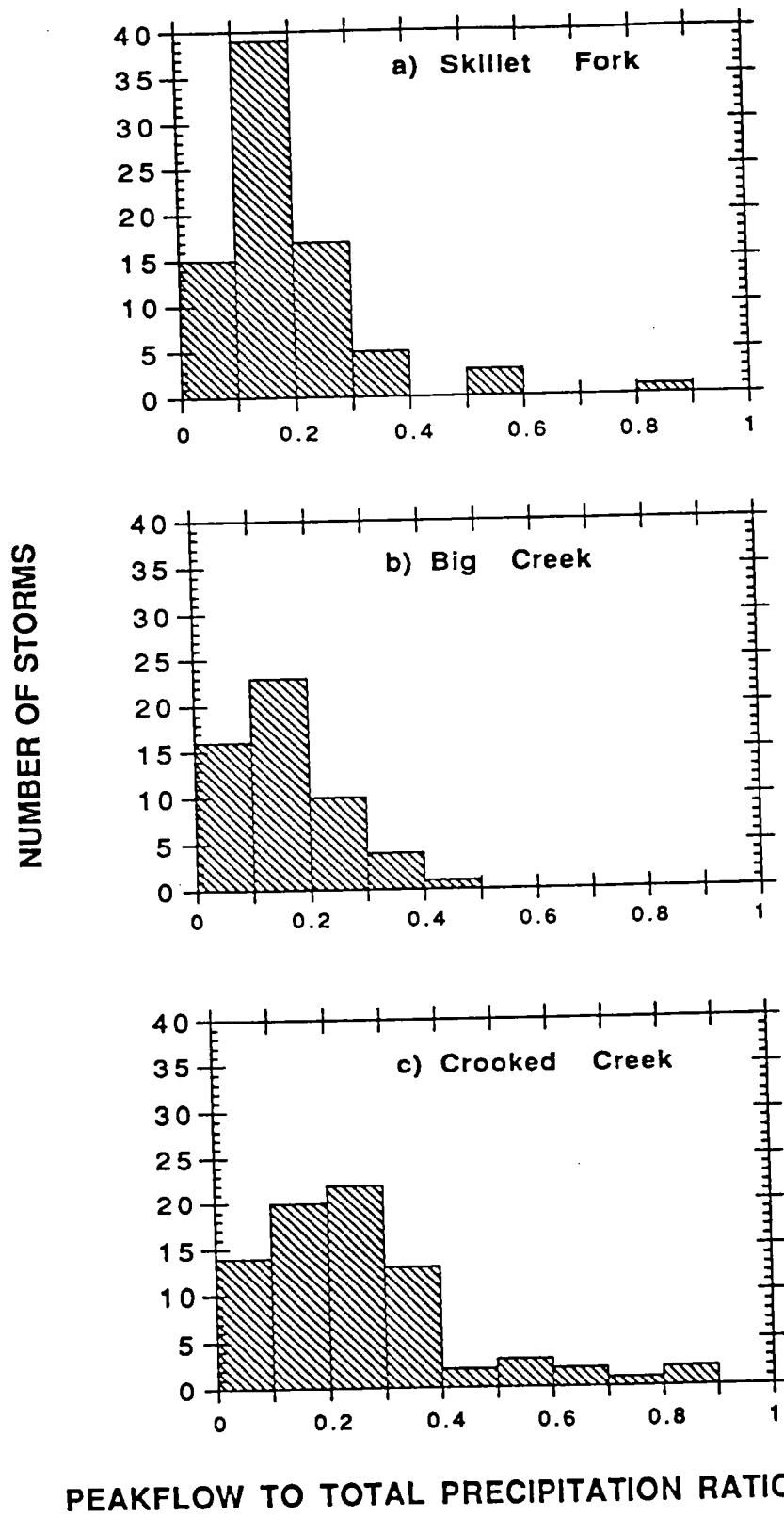
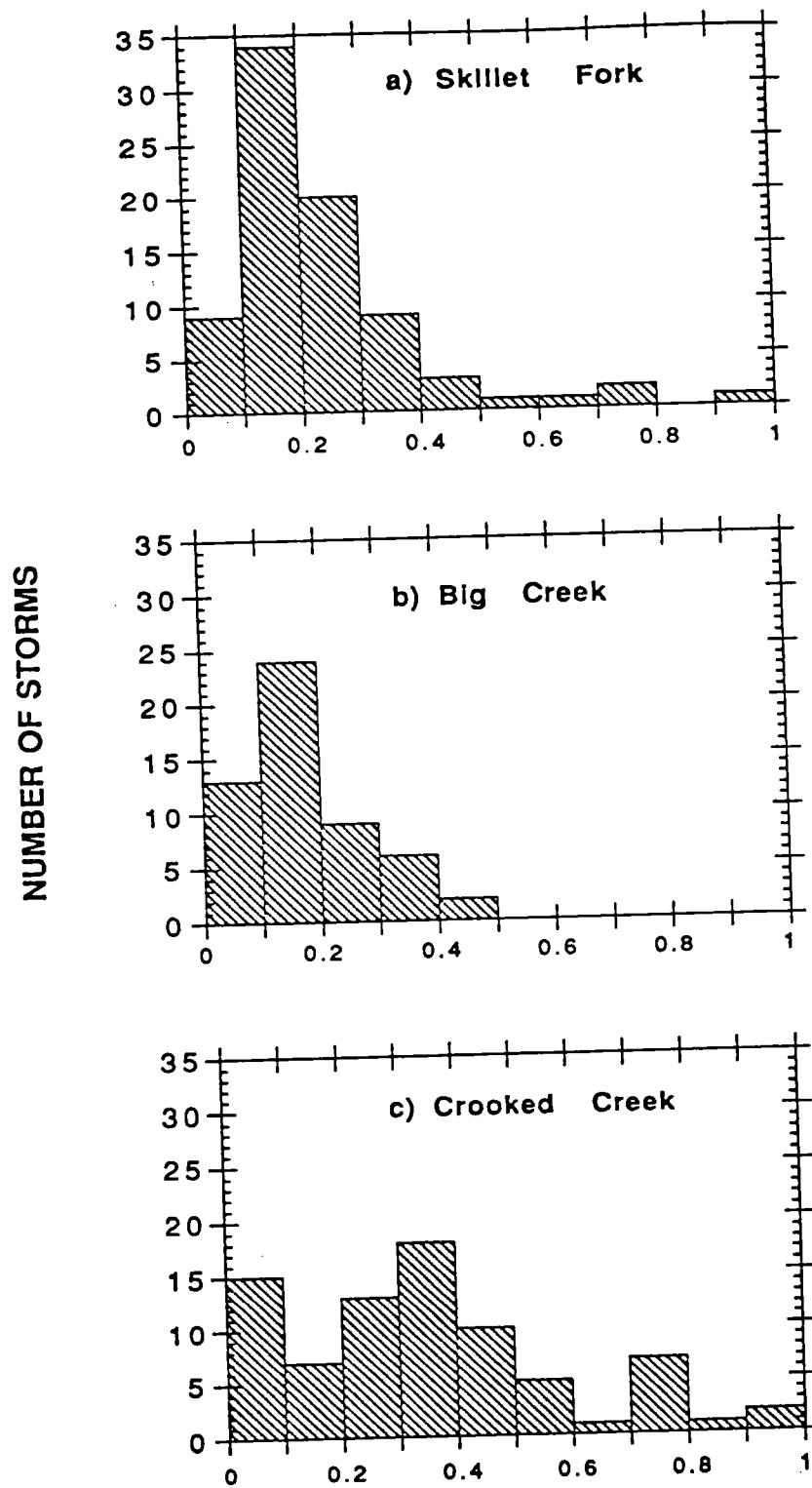


Figure 6. Frequency distribution of storm values of peakflow to total precipitation ratio for three selected stations



FLOODFLOW VOLUME TO TOTAL PRECIPITATION RATIO

Figure 7. Frequency distribution of floodflow volume to total precipitation ratio for three selected stations

Low Flow. For low-flow analysis, flow duration curves were used. The lower limb of the flow duration curve provides the means to choose a range of low-flow values for analysis. For each watershed, the corresponding flow duration curve was developed by using the daily streamflow data for the selected ten-year period. The low-flow parameters selected for analysis were the discharges at 95 and 99 percent probability of exceedance: Q_{95} and Q_{99} , respectively. The schematics of how the low flows were determined from the flow duration curve are illustrated in figure 8. The low-flow values in cfs were divided by the drainage areas and converted to inches per day. Each low-flow parameter was then plotted against the corresponding percentage of wetlands in the watershed to determine if any relationship existed.

To investigate the regional influence on the low-flow parameters, the parameter values were plotted by grouping the watersheds into the three regions: south, central, and north. To investigate the seasonal influence of wetlands on low flow, flow duration curves were developed and low-flow parameters were computed by grouping the data on the basis of the four seasons. For each station, the low-flow parameters for each season were then plotted against their percentages of wetlands.

Evaluation Procedure

For each flow parameter, the influence of wetlands on streamflow was studied using the linear regression analysis method. Regression analysis is a procedure for fitting an equation to a set of data. For a given set of measurements on two or more variables, regression analysis provides a means for finding coefficients $b_0, b_1, \dots, b_p$ in the regression model of the form:

$$y = b_0 + b_1 x_1 + \dots + b_p x_p \quad (1)$$

where y is the dependent variable and $x_1, \dots, x_p$ are the independent variables. The preceding equation is a general form of the linear multivariate model in which p is the

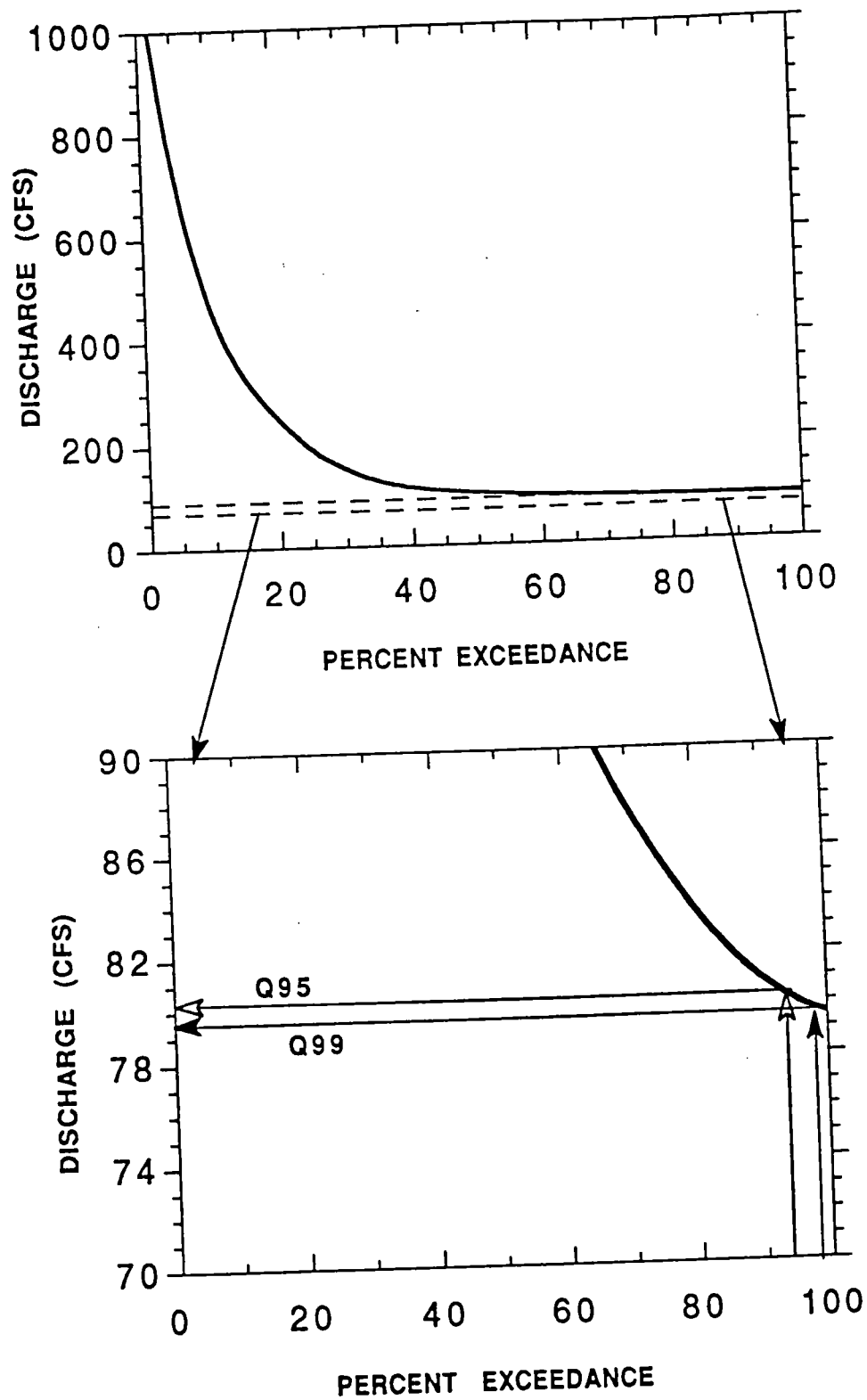


Figure 8. Determination of flows at different exceedance probabilities

number of independent variables, x_i is the i th independent variable, b_i is the i th slope coefficient, and b_0 is the intercept coefficient.

The values of the slopes and intercept in the above equation are computed using the principle of least squares. The principle of least squares is a process of obtaining the best estimate of the coefficients and is referred to as the regression method. Regression is the tendency for the expected value on one or more jointly correlated random variables to approach more closely the mean value of its set than any other. The principle of least squares is used to regress y on x_i values in equation (1). In a least-squares analysis, the error, e , or residual is defined as the difference between the predicted and measured values of the dependent variable:

$$e_i = y_i - \hat{y}_i \quad (2)$$

where $\hat{y}_i$ is the i th predicted value of y , y_i is the i th measured value of y , and e_i is the i th residual or error. The principle of least squares assumes that these errors are independent of each other and are normally distributed having a zero mean and a constant variance.

The objective function to minimize on the basis of the principle of least squares is the sum of squares of the errors, mathematically represented by:

$$F = \sum_{i=1}^n (y_i - \hat{y}_i)^2 \quad (3)$$

where n is the sample size. The function can be minimized by taking the derivative of F with respect to each unknown coefficient, setting these derivatives equal to zero, and then solving for the unknown coefficients.

In this study, percentage of wetlands in the watershed was the only independent variable while the streamflow parameters were the dependent variables.

Testing Method

The influence of wetlands on streamflow was examined by evaluating the percent change in each of the parameters for a one percent change in wetland area. For each flow parameter, a value was selected as the limiting or threshold percent change for an increase of one percent wetland area in the watershed. If the calculated percentage change of the parameter based on the best-fit regression line exceeded this threshold value, then the influence of wetlands on the streamflow parameter was considered to be significant.

The percentage change (PC) for each parameter for an increase of one percent wetland area in the watershed is computed as follows:

$$PC = 100 * S / y_{avg} \quad (4)$$

where S is the slope of the best fit regression line and y_{avg} is the average value of the parameter. The procedure is illustrated in figure 9.

The percent change concept was selected here instead of using the slope of the regression line to provide a meaningful interpretation of the relationship between percent wetland and other hydrologic parameters. Conceptually, PC represents by how much each parameter changes for one percent change in wetland area. We believe this concept is more understandable than providing the rate of change in the peakflow to average precipitation ratio or the floodflow volume to total precipitation ratio.

Based on the observation of the scatter plots and the regression lines of the streamflow parameters, the threshold percentage change was selected to be 0.5 percent. The significance of wetland influence on a streamflow parameter was then decided as follows:

$$|PC| \geq PC_t \rightarrow \text{wetland influence is significant} \quad (5)$$

$$|PC| < PC_t \rightarrow \text{wetland influence is not significant} \quad (6)$$

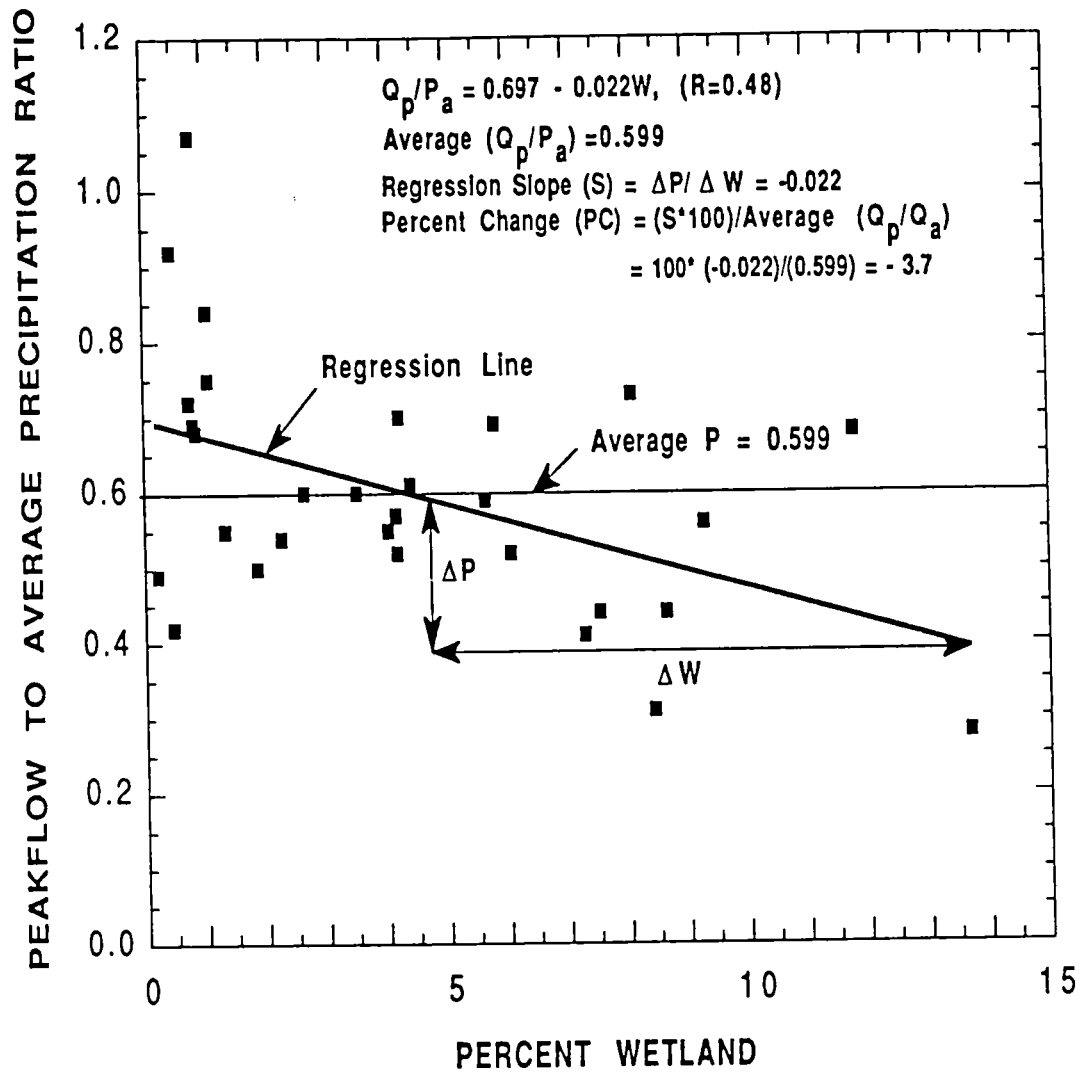


Figure 9. Percent change (PC) determination from regression parameters

where PC is the calculated percentage change for an increase of one percent wetland area in the watershed and PC_t is the threshold percentage change. The symbol $||$ implies absolute value. A positive (+) sign of the computed PC represents an increase in the parameter value and a negative (-) sign of the computed PC represents a decrease in the parameter value with increasing wetland percentage in the watershed.

RESULTS

The results of this study relating changes in peakflow, floodflow volume, and low flow to percent wetland change are presented in this section. The results are based on the statewide analysis where all the stations are included in one group, regional analysis where the stations are grouped into three regions, and seasonal analysis where the data have been segregated for the four seasons.

Peakflow and Floodflow Volume

Statewide Analysis

The results for the statewide analysis are shown in figures 10-13 and table 2. In general, the results of the analysis show that the peakflow and floodflow volume parameters decrease with increasing percentage of wetlands in the watersheds. For an increase of one percent wetland area in the watershed, the corresponding decreases are 3.7 percent for peakflow to average precipitation ratio, 2.6 percent for peakflow to peak precipitation ratio, and 3.0 percent for peakflow to total precipitation ratio. Thus among the three peakflow parameters analyzed, the peakflow to average precipitation ratio shows the most discernible relationship.

Table 2. Regression Analysis Results and Percent Change for Statewide Analysis

<i>Flow parameters</i>	<i>Regression coefficients</i>		<i>Percent change</i>
	<i>Intercept</i>	<i>Slope</i>	
Q_p/P_a	0.696	-0.022	-3.7
Q_p/P_p	0.369	-0.0086	-2.6
Q_p/P_t	0.286	-0.0075	-3.0
V/P_t	0.318	-0.0041	-1.4

The floodflow volume to total precipitation ratio decreases by 1.4 percent for an increase of one percent wetland area in the watershed (figure 13). The decrease in the floodflow volume parameter is significantly lower than for the peakflow parameters.

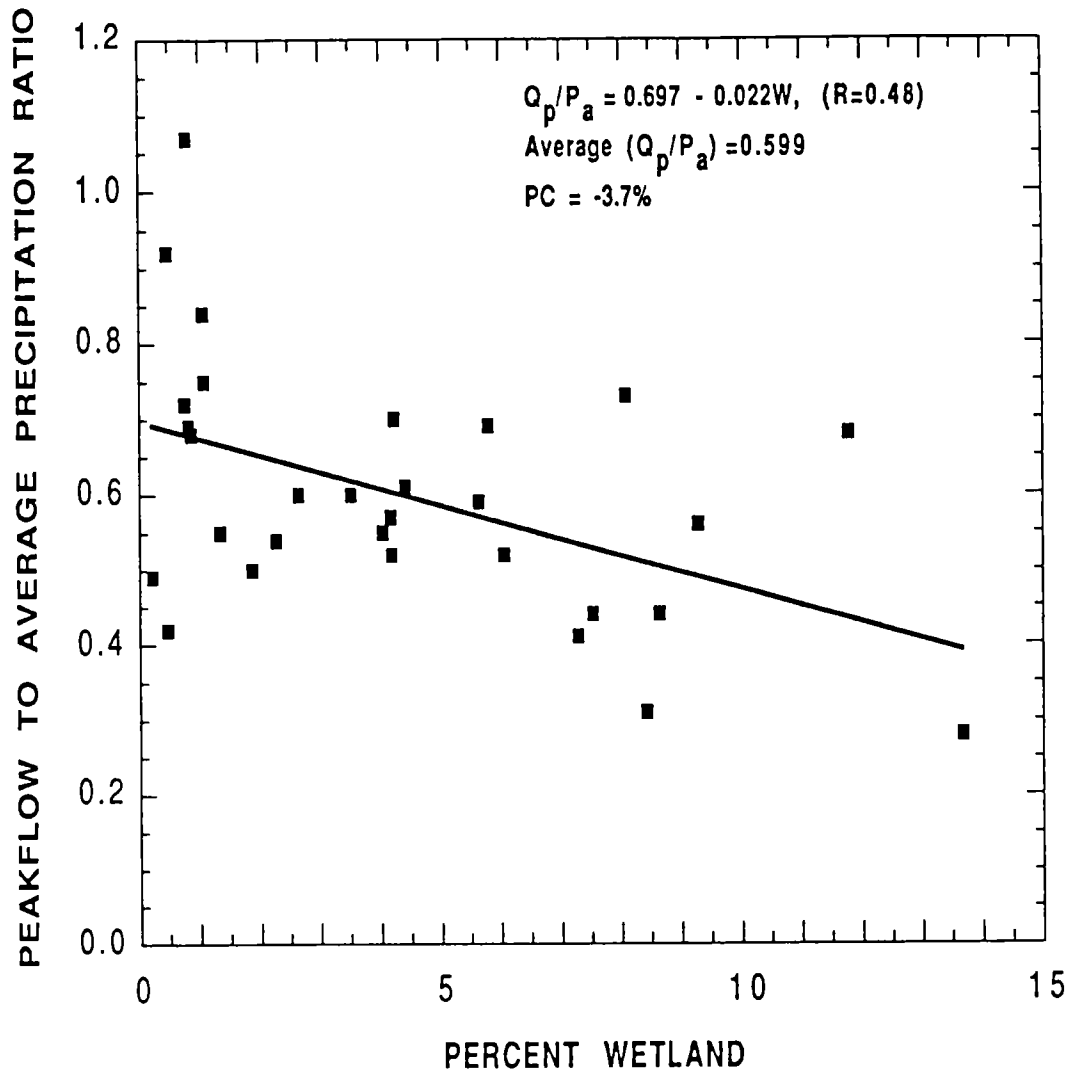


Figure 10. Relation between peakflow to average precipitation ratio and percent wetland for Illinois

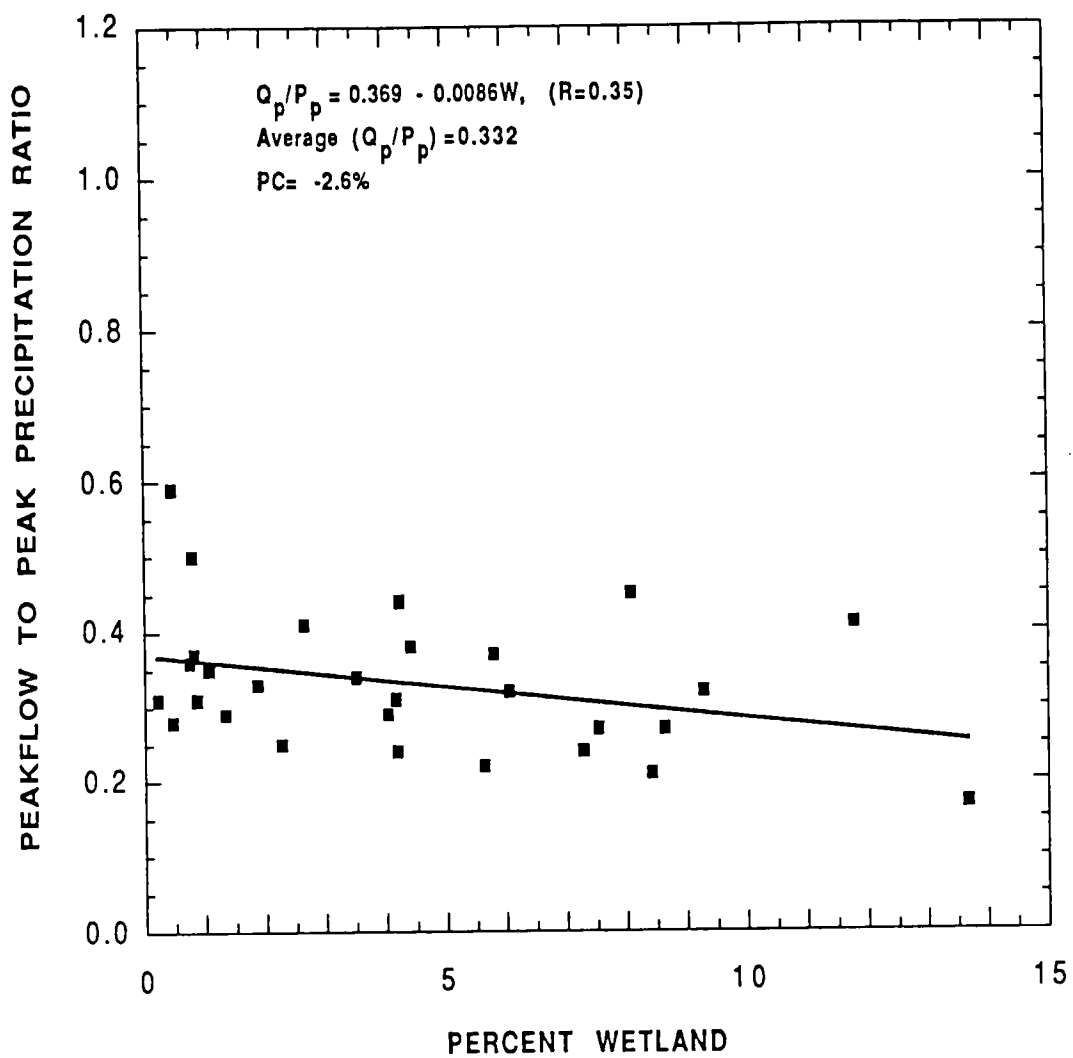


Figure 11. Relation between peakflow to peak precipitation ratio and percent wetland for Illinois

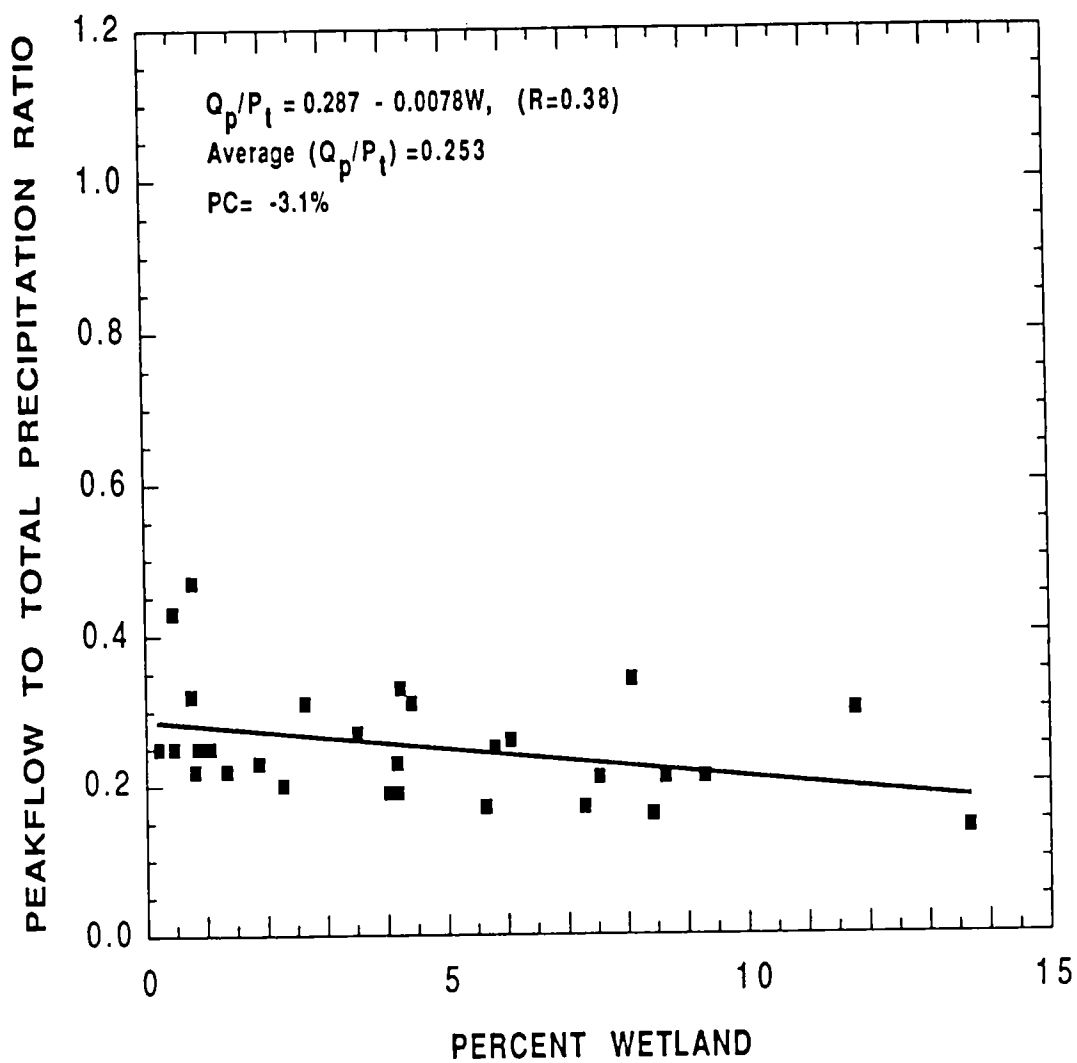


Figure 12. Relation between peakflow to total precipitation ratio and percent wetland for Illinois

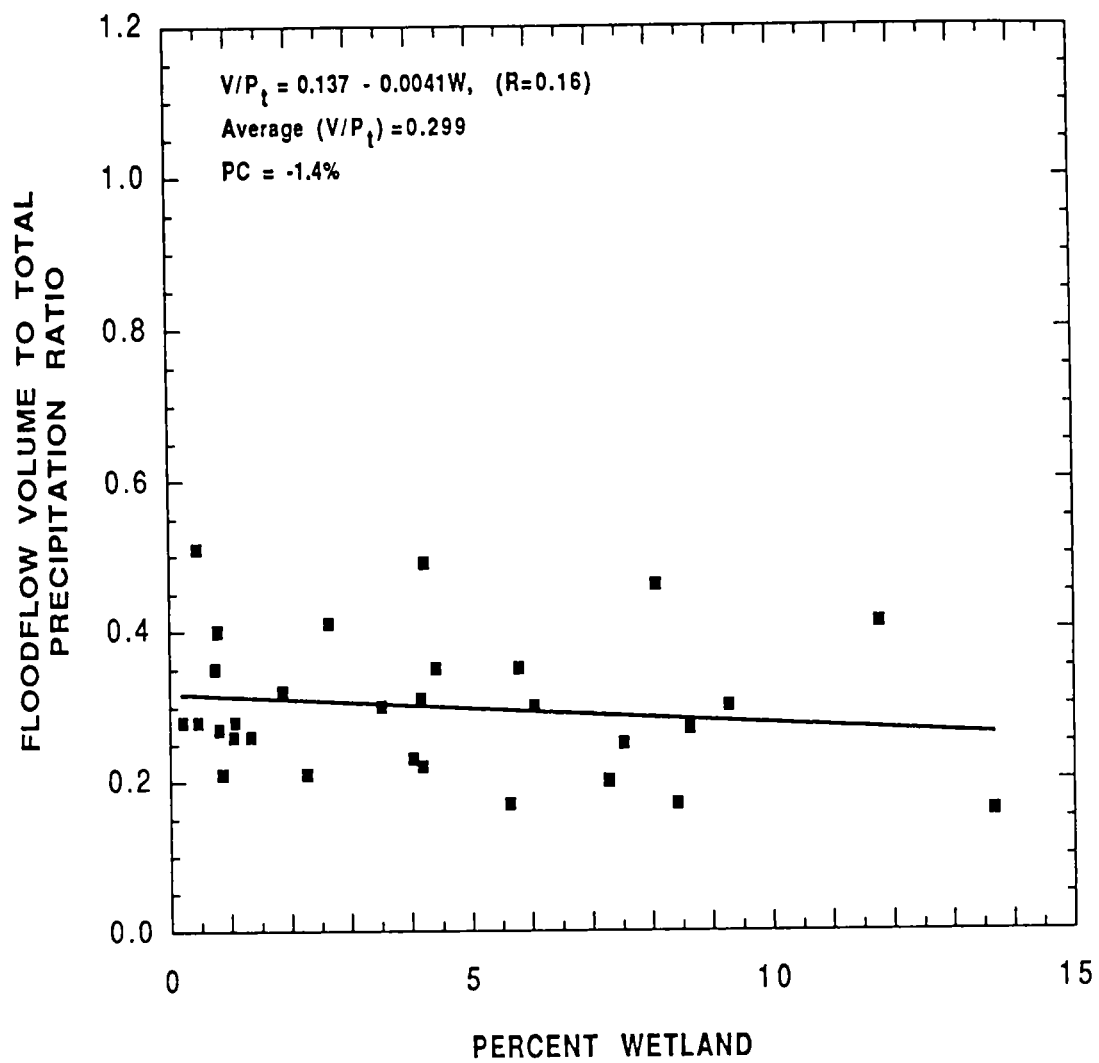


Figure 13. Relation between floodflow volume to total precipitation ratio and percent wetland for Illinois

Regional Analysis

The results from the regional analysis are summarized in figure 14 and table 3. The relations between the three peakflow parameters and percent wetland for the three regions are compared with the relation for the statewide analysis in figures 14a-14c. The analysis indicates that all three peakflow parameters decrease with increasing percentage of wetlands for central and northern Illinois. The peakflow to average precipitation ratio shows the most significant relationship. The percent decreases for central Illinois are 5.9, 4.9, and 5.0 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively. For northern Illinois the decreases for the three peakflow parameters are 7.9, 6.5, and 2.9 percent, respectively.

Table 3. Regional Regression Coefficients and Percent Change Values for Peakflow and Floodflow Parameters

<i>Flow parameter</i>	<i>Regression parameters</i>		<i>Slope</i>	<i>Percent change</i>
	<i>Region</i>	<i>Intercept</i>		
Q_p/P_a	statewide	0.696	-2.22	-3.7
	southern	0.601	0.53	0.8
	central	0.673	-3.29	-5.9
	northern	0.797	-4.78	-7.9
Q_p/P_p	statewide	0.369	-0.86	-2.6
	southern	0.320	0.57	1.6
	central	0.350	-1.44	-4.9
	northern	0.427	-2.20	-6.5
V/P_t	statewide	0.318	-0.41	-1.4
	southern	0.355	0.00	0.0
	central	0.294	-1.10	-5.9
	northern	0.304	-0.70	-7.9

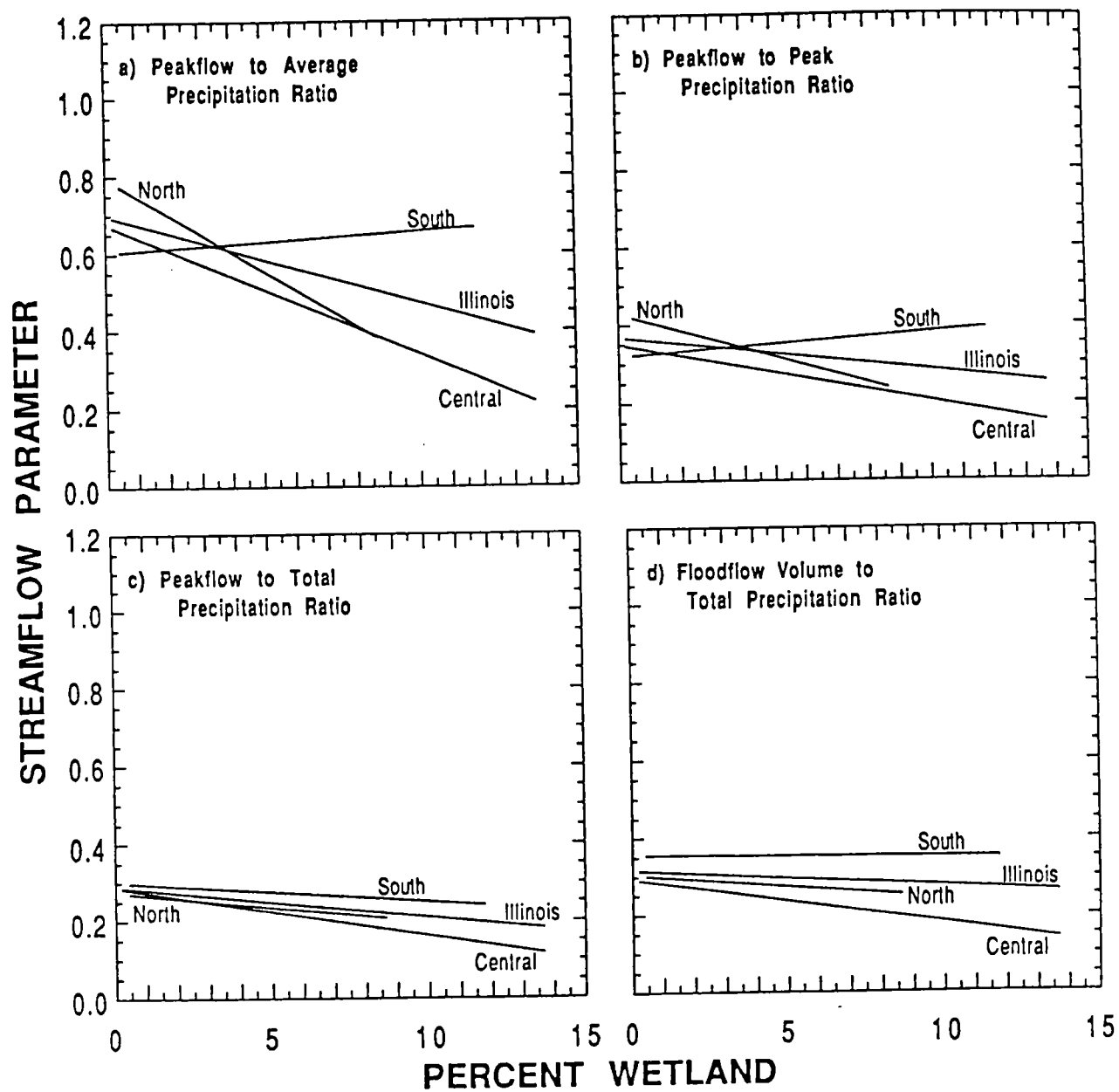


Figure 14. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland

In southern Illinois, peakflow to average precipitation ratio and peakflow to peak precipitation ratio increase by 0.8 and 1.6 percent, respectively, while peakflow to total precipitation ratio decreases by 1.9 percent. Thus, the relationships for southern Illinois are less noticeable and contradictory than those for central and northern Illinois.

The relations between the floodflow volume parameters and percent wetland for the three regions are compared in figure 14d. The floodflow volume to total precipitation ratio decreases for central and northern Illinois by 4.5 and 2.3 percent, respectively. For southern Illinois, however, the percentage of wetlands appears to have no influence on the floodflow volume ratio; it essentially remains constant irrespective of the percentage of wetlands in the watershed.

Seasonal Analysis

The influence of wetlands on streamflow could depend on seasonal variation of wetland functions and the general hydrologic cycle of precipitation, infiltration, storage, and runoff. In Illinois seasonal variations in precipitation, soil moisture and runoff are significant. Therefore it was decided to evaluate if significant differences in the influence of wetlands on streamflow could be detected based on available streamflow data. The selected flood events were grouped in the season they occurred and similar analyses were performed to evaluate the differences. The results are also compared to the total set of data.

The results from the seasonal analysis are summarized in figures 15-19 and tables 4-7. The seasonal analysis indicates that all three peakflow parameters decrease with increasing percentage of wetlands for all seasons. The greatest decrease is found in the fall and the least during winter. The percent decreases in fall, for an increase of one percent wetland area in the watershed, are 5.7, 4.1, and 5.6 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively. The corresponding values for winter are 2.4, 1.6, and 1.4

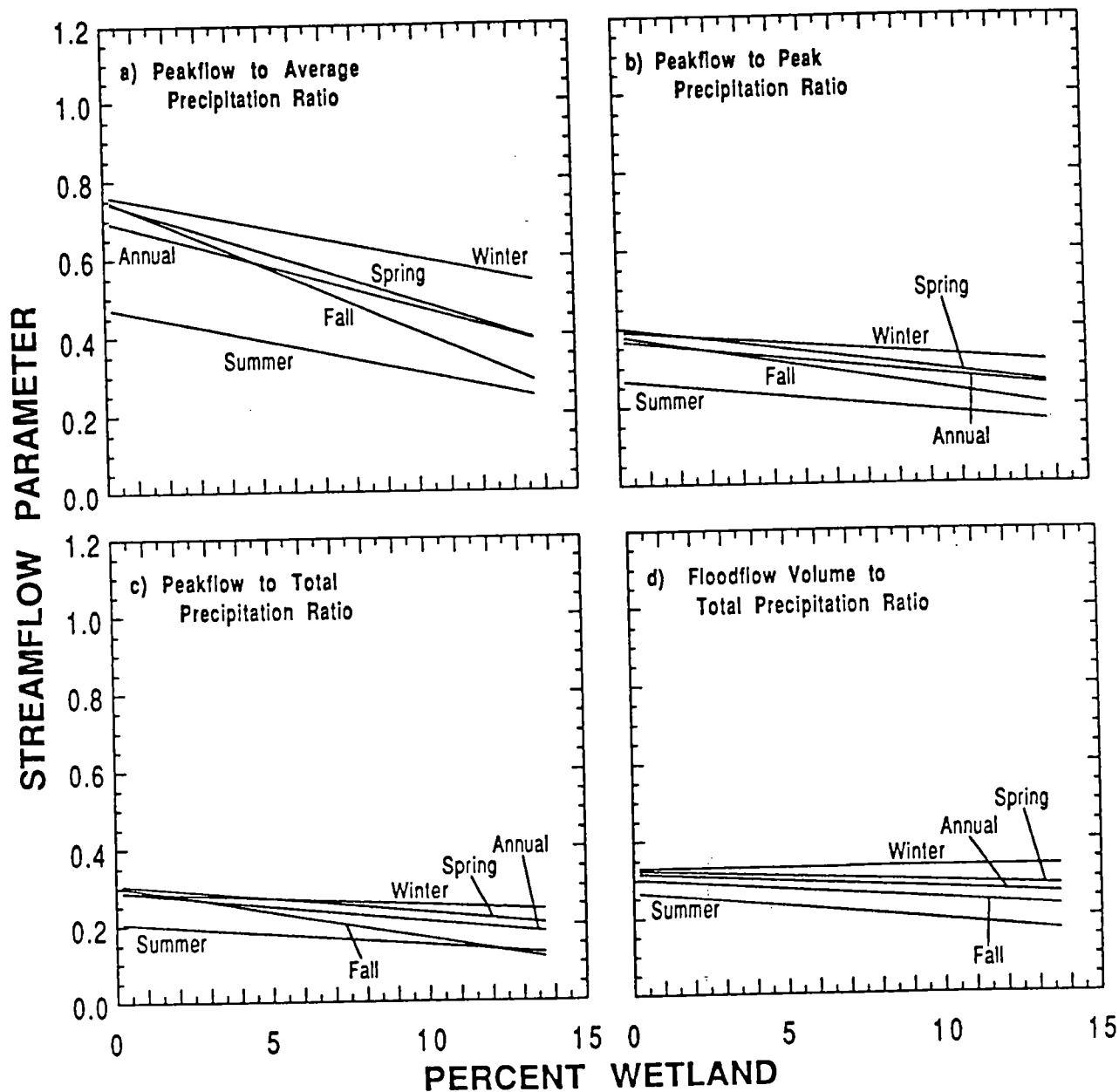


Figure 15. Seasonal variation of the relations between peakflow and floodflow volume parameters and percent wetland

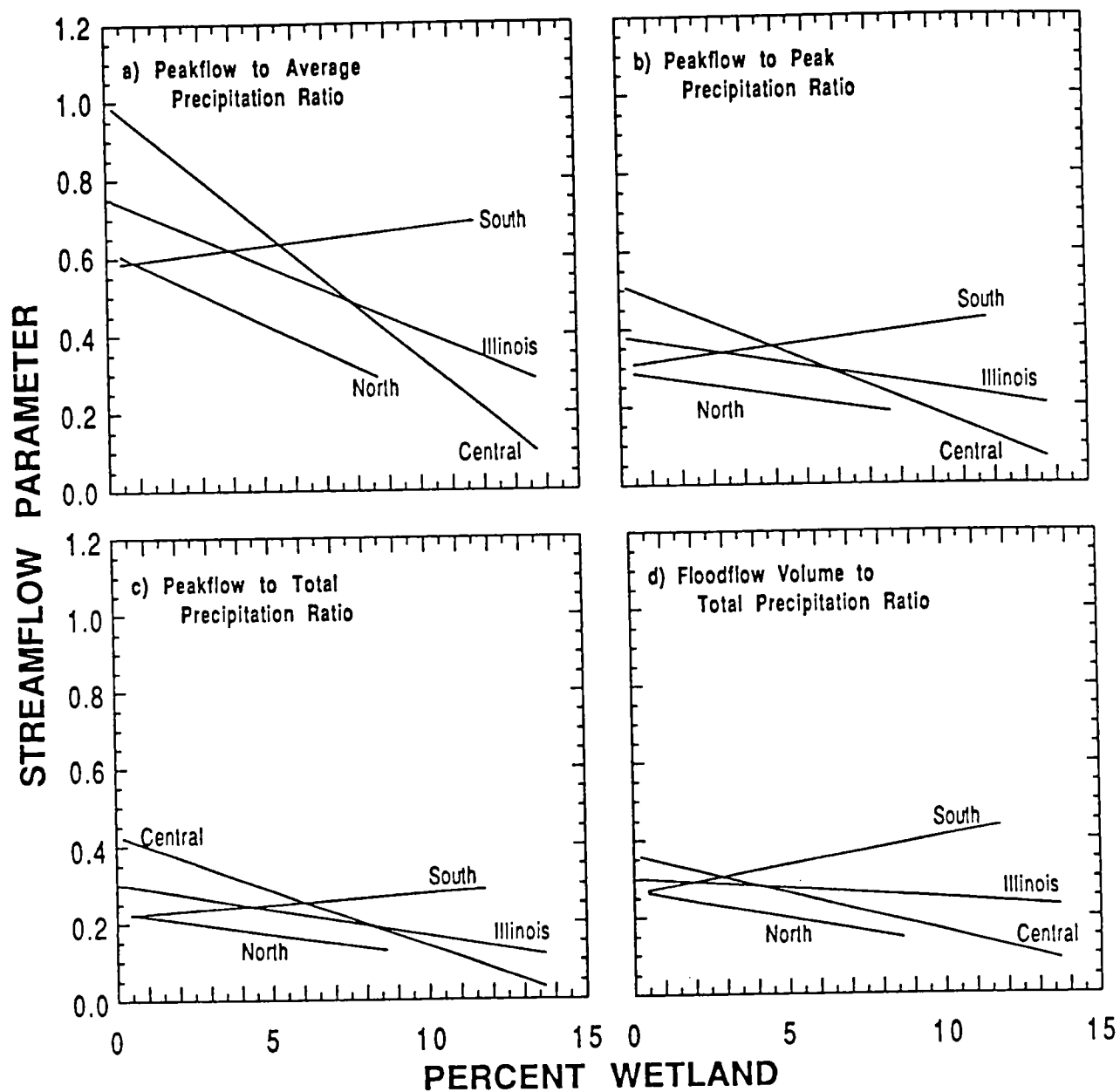


Figure 16. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for fall

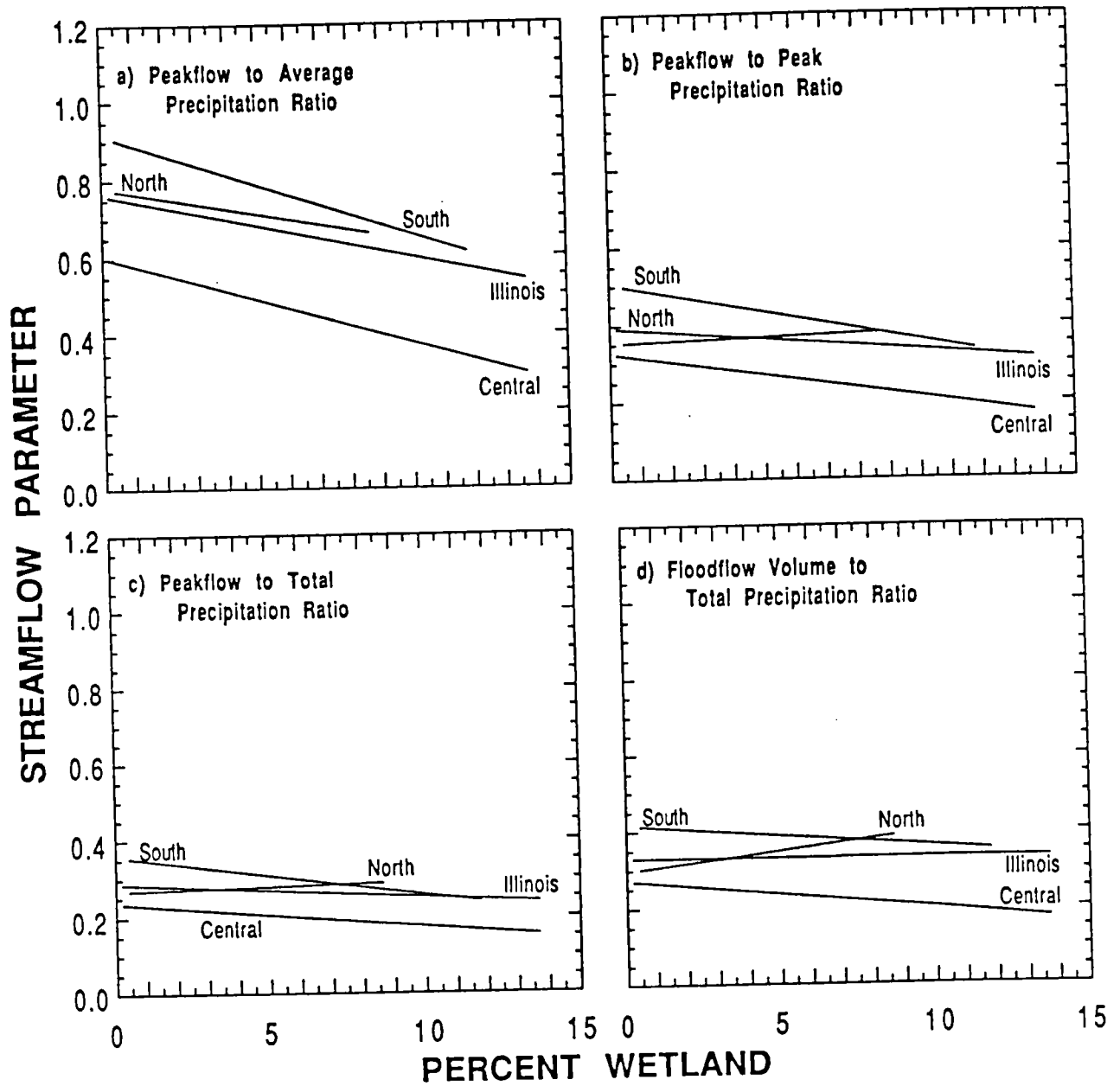


Figure 17. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for winter

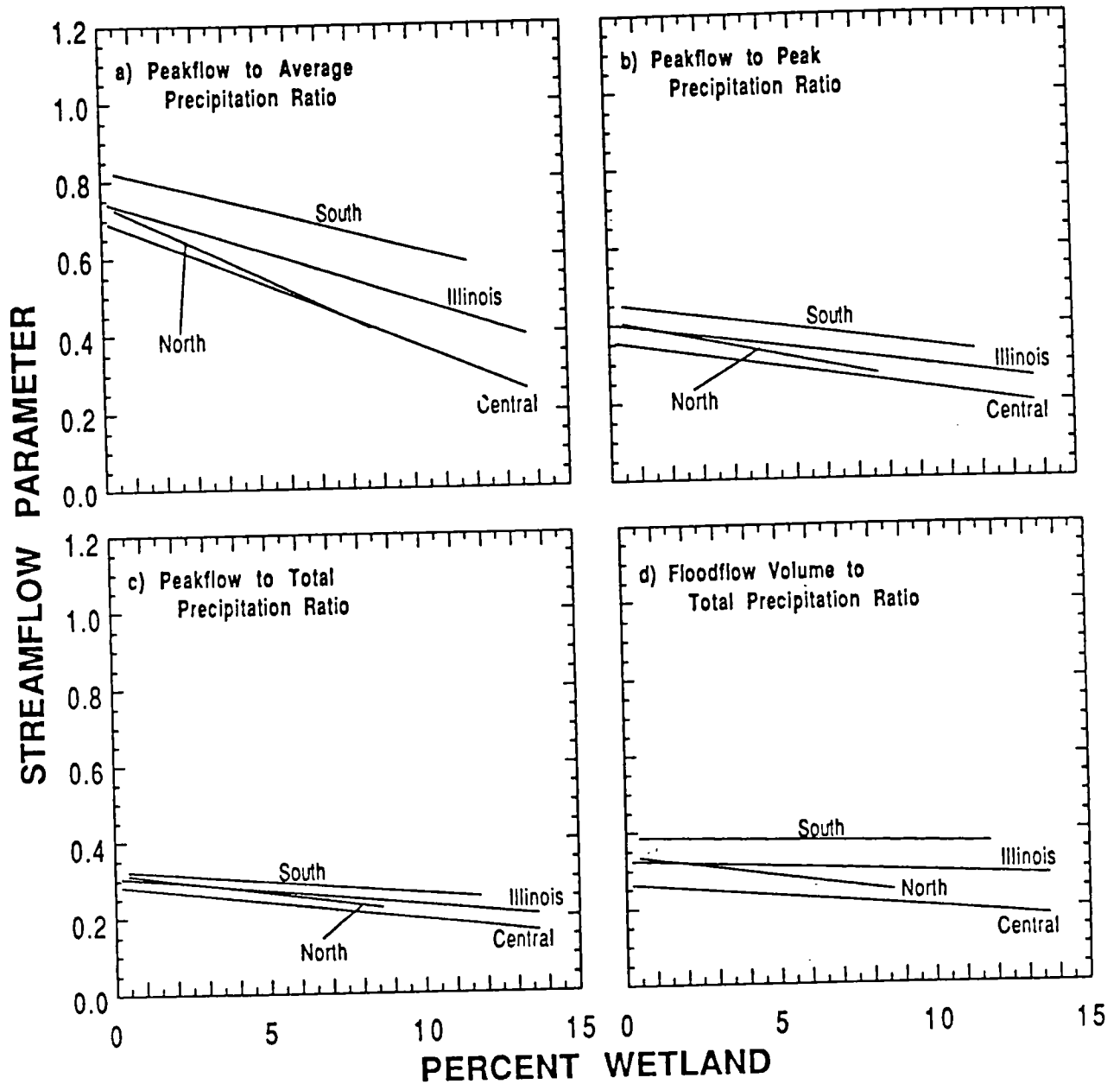


Figure 18. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for spring

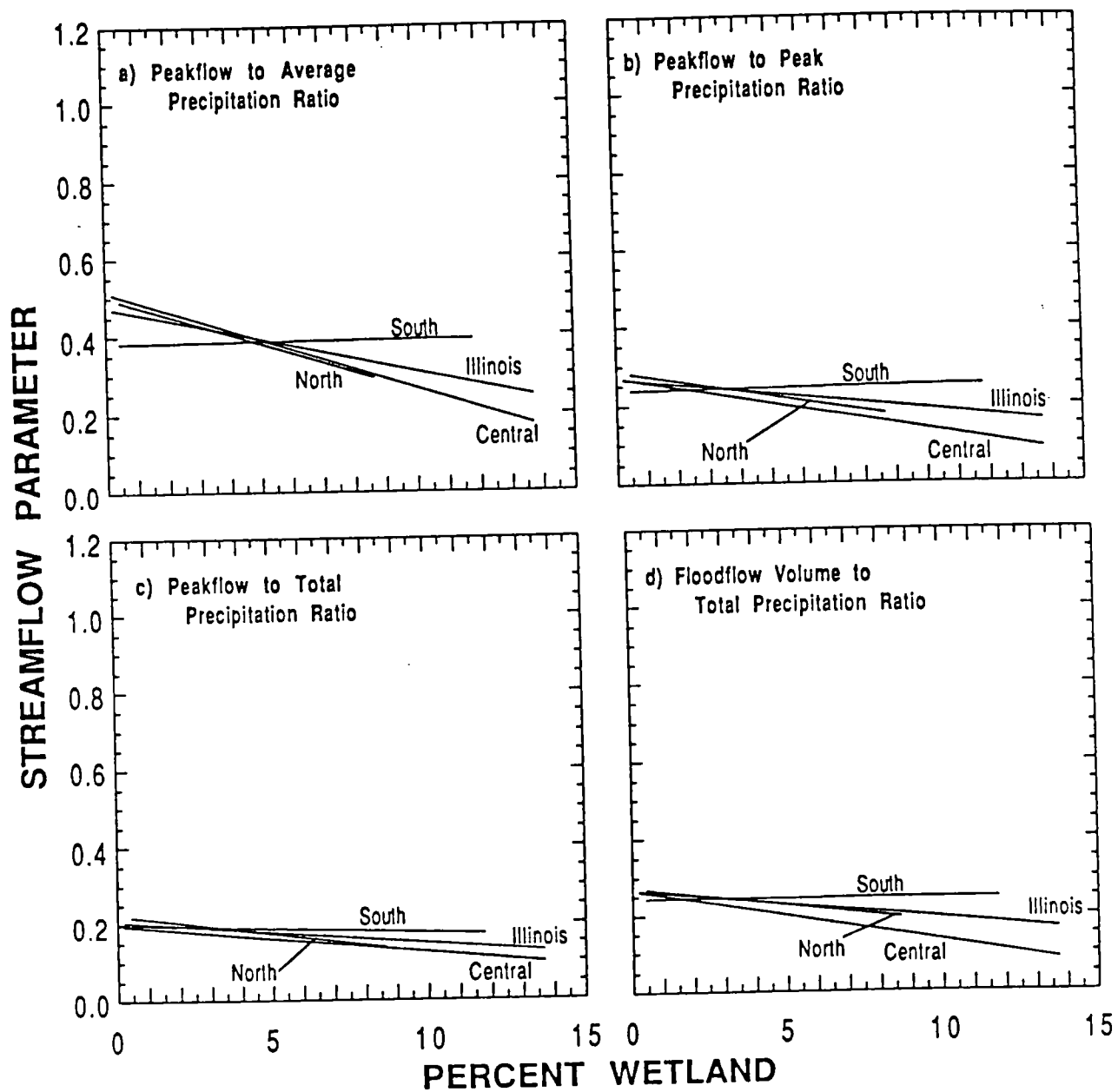


Figure 19. Regional variation of the relations between peakflow and floodflow volume parameters and percent wetland for summer

Table 4. Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Average Precipitation Ratio (Q_p/P_a) for a One Percent Change in Wetland Area

	<i>Annual</i>	<i>Fall</i>	<i>Winter</i>	<i>Spring</i>	<i>Summer</i>
Illinois (statewide)	-3.7	-5.7	-2.4	-4.0	-4.2
South	+0.8	+1.5	-3.3	-2.9	+0.3
Central	-5.9	-8.7	-4.3	-5.3	-5.9
North	-7.9	-8.2	-1.9	-6.5	-6.1

Table 5. Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Peak Precipitation (Q_p/P_p) for a One Percent Change in Wetland Area

	<i>Annual</i>	<i>Fall</i>	<i>Winter</i>	<i>Spring</i>	<i>Summer</i>
Illinois (statewide)	-2.6	-4.1	-1.6	-2.8	-3.8
South	1.6	2.7	-3.4	-2.7	+0.5
Central	-4.9	-8.3	-4.0	-3.6	-6.0
North	-6.5	-5.1	0.8	-4.6	-5.5

Table 6. Influence of Wetlands on Peakflow as Measured by the Percent Change in the Ratio of Peakflow to Total Precipitation (Q_p/P_t) for a One Percent Change in Wetland Area

	<i>Annual</i>	<i>Fall</i>	<i>Winter</i>	<i>Spring</i>	<i>Summer</i>
Illinois (statewide)	-3.0	-5.6	-1.4	-2.7	-3.4
South	-1.9	2.3	-3.5	-2.2	-1.4
Central	-5.0	-9.0	-3.0	-3.5	-4.4
North	-2.9	-6.2	0.9	-3.8	-5.6

Table 7. Influence of Wetlands on Floodflow Volume as Measured by the Percent Change in the Ratio of Floodflow Volume to Total Precipitation (V/P_t) for a One Percent Change in Wetland Area

	<i>Annual</i>	<i>Fall</i>	<i>Winter</i>	<i>Spring</i>	<i>Summer</i>
Illinois (statewide)	-1.4	-2.0	0.0	-1.0	-3.1
South	0.0	+4.4	-1.5	-0.6	+0.2
Central	-5.9	-8.7	-4.3	-5.3	-5.9
North	-7.9	-8.2	-1.9	-6.5	-6.1

percent. The decreases in peakflow parameters for spring and summer are very similar; for spring, the decreases are 4.0, 2.8, and 2.7 percent; and for summer, the decreases are 4.2, 3.4, and 3.4 percent. The peakflow ratios for the four seasons are compared in figures 15a-15c.

The relationships for the floodflow volume parameter are much less perceptible than those for the peakflow parameter. The decreases for floodflow volume for fall, winter, spring, and summer are 2.0, 0.0, 1.0, and 3.1 percent, respectively. Figure 15d compares the floodflow volume ratio for the four seasons.

Seasonal-Regional

Since the storm events were separated on the basis of the season in which they occurred for the seasonal analysis discussed in the preceding section, it was decided to evaluate if the general seasonal patterns vary from region to region within Illinois. In a similar fashion as was done for the regional analysis, the data for the seasonal analysis were grouped into regions to assess the seasonal influence in different regions of the state. A summary of the statewide analysis is provided in the seasonal analysis discussed in the preceding section. The regional aspect of the seasonal analysis is presented in the following sections. The results of this analysis are provided in figures 16-19 and tables 4-7.

Fall. The results for the fall season are shown in figure 16. The results show that all the peakflow parameters decrease with increasing percentage of wetlands for both central and northern Illinois. The decreases for central Illinois are 8.7, 8.3, and 9.0 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively. The decreases for northern Illinois are 8.2, 5.1, and 6.2 percent, respectively. For southern Illinois, however, the peakflow ratios increase with increasing percentage of wetlands: the increases are 1.5, 2.7, and 2.3 percent, respectively. Among the three peakflow parameters, the most noticeable

relationship is for the peakflow to average precipitation ratio. Among the three regions, the relationships for central and northern Illinois are more perceptible.

The floodflow volume parameter exhibits results similar to the peakflow parameters, where the parameter decreases in northern and central Illinois and increases in southern Illinois (figure 16c). The decreases for central and northern Illinois are 6.9 percent and the increase for southern Illinois is 4.4 percent.

Winter. The results for the winter season are summarized in figure 17. The results show that, in general, the peakflow parameters decrease with increasing percentage of wetlands in the watershed for southern and central Illinois. The decreases for southern Illinois are 3.3, 3.4, and 3.5 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively. The decreases for central Illinois are 4.3, 4.0, and 3.0 percent, respectively. For northern Illinois, only peakflow to average precipitation ratio decreases by 1.9 percent, while peakflow to peak precipitation ratio and peakflow to total precipitation ratio increase by 0.8 and 0.9 percent, respectively. Among the three peakflow parameters, the most noticeable relationship is for peakflow to average precipitation ratio. Among the three regions, the relationship for central Illinois is the most perceptible.

The floodflow volume parameter exhibits similar results to those of the peakflow parameters (figure 16d). The floodflow volume to total precipitation ratio decreases by 1.5 and 3.0 percent for southern and central Illinois, and increases by 3.1 percent for northern Illinois.

Spring. The results for the spring season are shown in figure 18. The results show that the peakflow parameters decrease with increasing percentage of wetlands for all three regions. The decreases for southern Illinois are 2.9, 2.7, and 2.2 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively, for an increase of one percent wetland area in the watershed. The corresponding decreases for central Illinois are 5.3, 3.6, and

3.5 percent and for northern Illinois they are 6.5, 4.6, and 3.8 percent. Among the three peakflow ratios, the most significant relationship is for peakflow to average precipitation ratio. Among the three regions, the relationship for northern Illinois is the most perceptible.

The floodflow volume parameter also decreases with increasing wetland percentage for all three regions (figure 18d). The decreases are 0.6, 2.3, and 3.7 percent for southern, central, and northern Illinois, respectively.

Summer. The results for the summer season are shown in figure 19. The results show that the peakflow parameters decrease with increasing percentage of wetlands in the watershed for central and northern Illinois. The decreases for central Illinois are 5.9, 6.0, and 4.4 percent for peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio, respectively, for an increase of one percent wetland area in the watershed. The corresponding decreases for northern Illinois are 6.1, 5.5, and 5.6, for southern Illinois, peakflow to average precipitation ratio is not significantly influenced by the presence of wetlands, peakflow to peak precipitation ratio increases by 0.5 percent, while peakflow to total precipitation ratio decreases by 1.4 percent. Among the three peakflow ratios, the most significant relationship is for peakflow to average precipitation ratio. Among the three regions, the relationship for central and northern Illinois are more perceptible.

Similar to the peakflow parameters, the floodflow volume parameters also decrease by 6.1 and 4.1 percent for central and northern Illinois, respectively. For southern Illinois, however, floodflow volume is not significantly affected by the percentage of wetlands in the watershed.

Low Flow

Statewide Analysis

The results from the low-flow analysis for the state as a whole are shown in figures 20-21 and tables 8 and 9. The results indicate that flows at both 95 and 99 percent probability of exceedance (Q_{95} and Q_{99}) generally increase with increasing wetland percentage in the watershed. For the whole state, the percent increases for Q_{95} and Q_{99} for an increase of one percent wetland area in the watershed are 7.9 and 8.4 percent, respectively. As figures 20 and 21 show, there is a wide scatter in the data points for both Q_{95} and Q_{99} for Illinois as a whole; however, the scatter in the data can be considerably reduced for both the low-flow parameters when they are grouped on a regional basis.

Regional Analysis

The results from the regional analysis are also shown in figures 20-21 and table 8. The results indicate that both low-flow parameters increase with increasing percentage of wetlands. The percent increases for Q_{95} and Q_{99} for southern Illinois are 15.9 and 17.2 percent, respectively. For northern Illinois, the increases are 15.0 and 18.2 percent, respectively. The influence of wetlands on low flow is significantly less in central Illinois compared to that in either southern or northern Illinois. Q_{95} increased by 5.5 percent, while Q_{99} shows a decrease of 4.6 percent. Thus, based on the data analyzed, influence of wetlands on low flow is more dominant in southern and northern Illinois than in central Illinois.

Seasonal Analysis

The results from the seasonal analysis are shown in figure 22 and table 9. The seasonal analysis indicates that both Q_{95} and Q_{99} increase with increasing wetland percentage for fall. The percent increases in fall are 8.4 and 9.2 percent for Q_{95} and Q_{99} , respectively. The relationships are similar for winter and summer. The percent increases

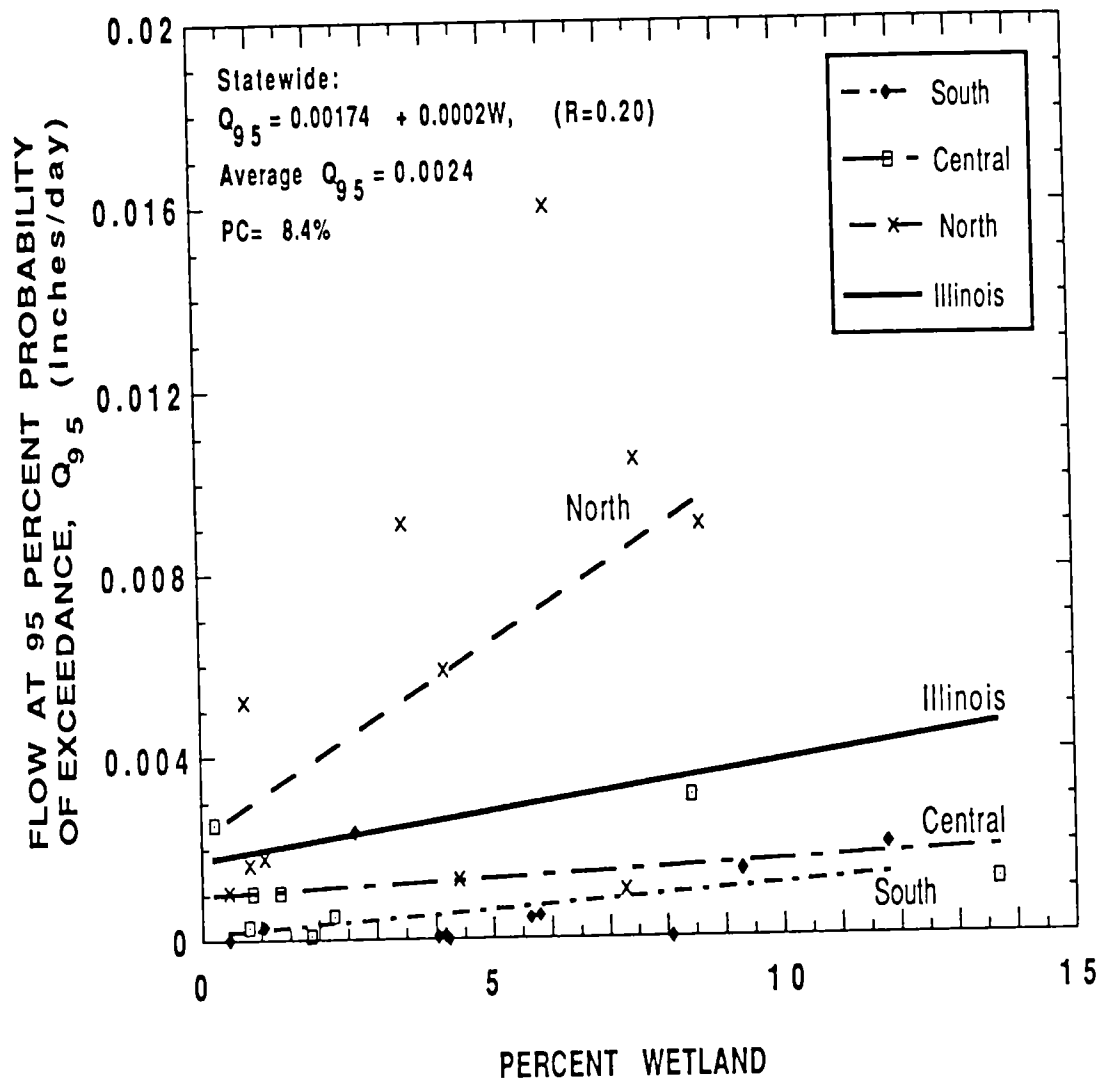


Figure 20. Relation between low-flow parameter, Q_{95} , and percent wetland for Illinois

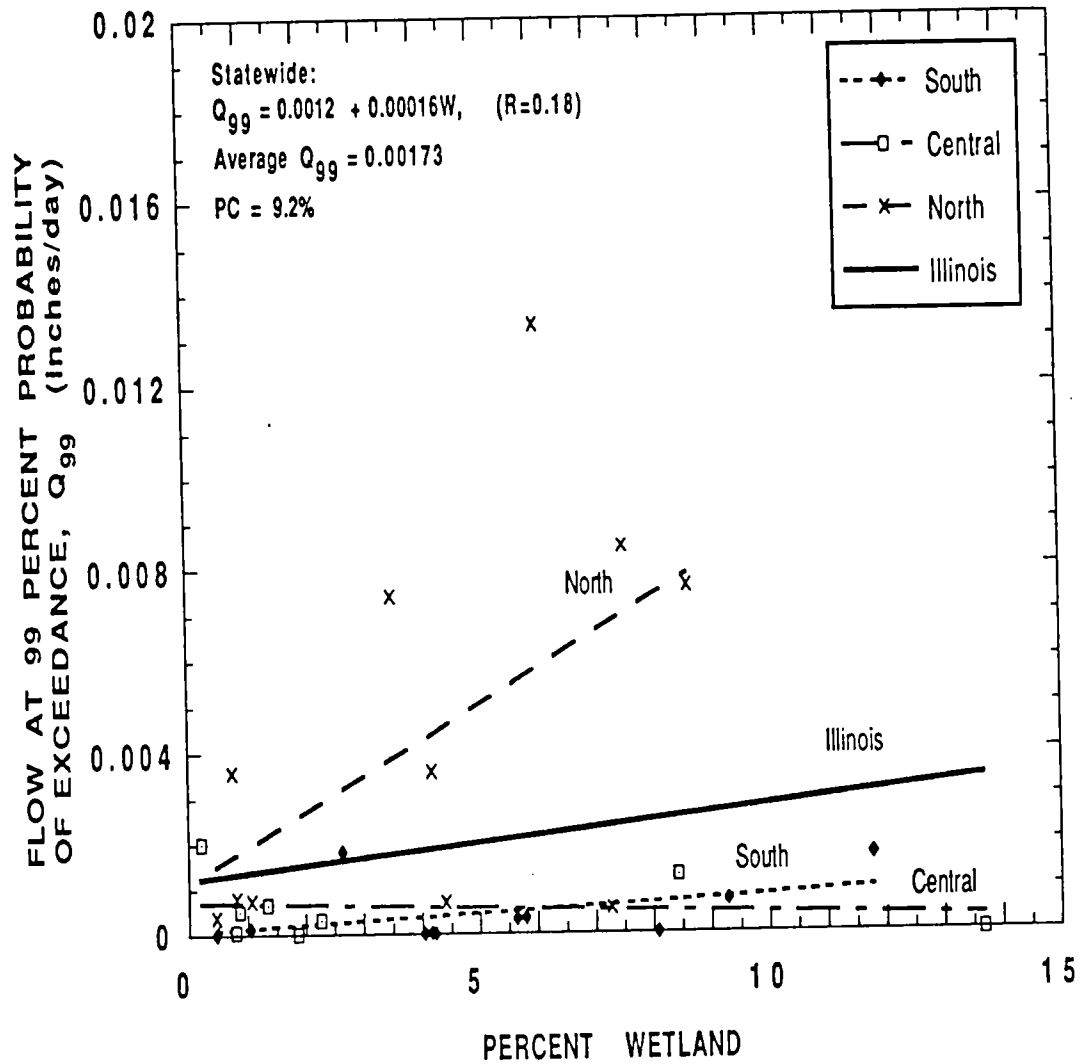


Figure 21. Relation between low-flow parameter, Q_{99} , and percent wetland for Illinois

Table 8. Regional Variability of Influence of Wetlands on Low Flow in Illinois
as Measured by the Percent Change in Q95 and Q99

	<i>Q95</i> (percent change)	<i>Q99</i> (percent change)
Illinois (statewide)	+7.9	+8.4
Southern Illinois	+15.9	+17.2
Central Illinois	+5.5	-4.6
Northern Illinois	+15.0	+18.2

Table 9. Seasonal Variability of Influence of Wetlands on Low Flow in Illinois
as Measured by the Percent Change in Q95 and Q99

	<i>Q95</i> (percent change)	<i>Q99</i> (percent change)
Annual	+7.9	+8.4
Fall	+8.4	+9.2
Winter	+7.6	+7.6
Spring	-1.8	-2.4
Summer	+8.0	+9.4

Notes:

Q95 = flow at 95 percent probability of exceedance

Q99 = flow at 99 percent probability of exceedance

+ = parameter value increases with increasing wetland percentage

- = parameter value decreases with increasing wetland percentage

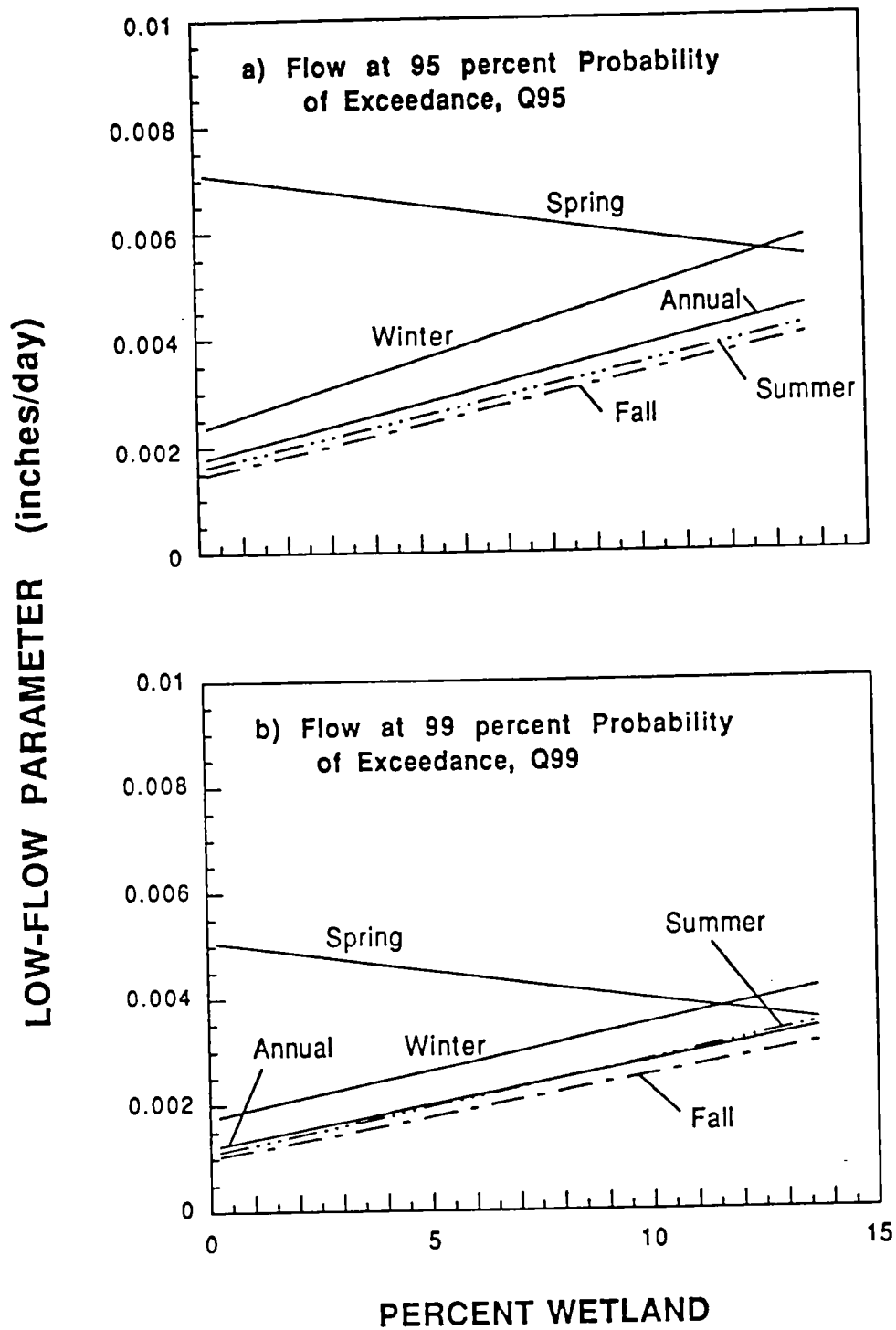


Figure 22. Seasonal variation of the relation between parameters Q95 and Q99 and percent wetland low flow

in winter are 7.6 percent for both Q95 and Q99, while the percent increases in summer are 8.0 and 9.4 percent for Q95 and Q99, respectively. For spring, however, Q95 and Q99 decrease by 1.8 and 2.4 percent, respectively.

Seasonal-Regional

As mentioned previously, low-flow parameters were computed for each season by grouping the data on the basis of the four seasons. The following sections discuss the seasonal influence for the different regions. The results of this analysis are summarized in table 10.

Fall. The results show that both Q95 and Q99 increase with increasing wetland percentage in the watershed for southern as well as northern Illinois. The increases for southern Illinois are 17.2 and 19.3 percent for Q95 and Q99, respectively. The increases for northern Illinois are 15.6 and 18.7 percent, respectively. For central Illinois, however, Q95 increases by 6.4 percent, while Q99 decreases by 2.8 percent. Thus the relationships for southern and northern Illinois show more influence of wetlands on low flow compared to central Illinois for fall. The rate of increase is, however, much higher for northern Illinois than that for southern Illinois.

Winter. The results show that both Q95 and Q99 increase with increasing wetland percentage in the watershed for all three regions: southern, central, and northern Illinois during winter. The percent increases for southern Illinois are 9.1 and 8.9 percent for Q95 and Q99, respectively. The percent increases for central Illinois are 10.2 and 5.7 percent, respectively. The percent increases for northern Illinois are 12.9 and 14.1 percent, respectively. Thus the relationships for all three regions in Illinois show similar influence of wetlands on low flow for winter. The rate of increase is again higher for northern Illinois than that for either southern or central Illinois.

Spring. The results show that for all three regions - southern, central, and northern Illinois - Q95 as well as Q99 are influenced much less by wetlands in spring than

Table 10. Seasonal Variability of Influence of Wetlands on Low Flow by Region
in Illinois as Measured by the Percent Change in Q₉₅ and Q₉₉

	<i>Fall</i>		<i>Winter</i>		<i>Spring</i>		<i>Summer</i>	
	<i>Q₉₅</i>	<i>Q₉₉</i>	<i>Q₉₅</i>	<i>Q₉₉</i>	<i>Q₉₅</i>	<i>Q₉₉</i>	<i>Q₉₅</i>	<i>Q₉₉</i>
Illinois	+8.4	+9.2	+7.6	+7.0	-1.8	-2.4	+8.0	+9.4
Southern Illinois	+17.2	+19.3	+9.1	+8.9	-0.4	+5.3	+22.0	+20.9
Central Illinois	+6.4	-2.8	+10.2	+5.7	-2.1	-4.2	-4.7	-8.0
Northern Illinois	+15.6	+18.7	+12.9	+14.1	+3.8	+2.2	+16.2	+20.0

Notes:

Q₉₅ = flow at 95 percent probability of exceedance

Q₉₉ = flow at 99 percent probability of exceedance

+ = parameter value increases with increasing wetland percentage

- = parameter value decreases with increasing wetland percentage

in the other seasons. For southern Illinois, Q₉₅ is not significantly influenced by wetlands in spring, while Q₉₉ shows an increase of 5.3 percent. For central Illinois, there are decreases of 2.1 and 4.2 percent for Q₉₅ and Q₉₉, respectively. For northern Illinois, there are increases of 3.8 and 2.2 percent for Q₉₅ and Q₉₉, respectively.

Summer. The results show that both Q₉₅ and Q₉₉ increase with increasing wetland percentage in the watershed for southern as well as northern Illinois. The increases for southern Illinois are 22.0 and 20.9 percent for Q₉₅ and Q₉₉, respectively. The increases for northern Illinois are 16.2 and 20.0 percent, respectively. For central Illinois, however, Q₉₅ and Q₉₉ decreases by 4.7 and 8.0 percent, respectively. Thus the relationships for southern and northern Illinois show more influence of wetlands on low flow compared to central Illinois. The rate of increase is again much higher for northern Illinois than that for southern Illinois.

SUMMARY AND CONCLUSIONS

Existing streamflow records from 30 gaging stations in different geographic regions of Illinois with different percentages of wetlands in their watersheds were analyzed to assess the influence of wetlands on streamflow. The objective of the research was to determine if streamflow parameters were influenced by the percentage of wetlands in the watersheds. The streamflow parameters analyzed included three peakflow parameters (peakflow to average precipitation ratio, peakflow to peak precipitation ratio, and peakflow to total precipitation ratio), a floodflow parameter (floodflow volume to total precipitation ratio), and two low-flow parameters (flows at 95 and 99 percent exceedance probability, Q_{95} and Q_{99}). Because of significant regional differences in physiography and hydrology in Illinois, the data were synthesized to evaluate if there were regional patterns in the relations. The stations were grouped into three regions, northern, central, and southern Illinois. Even though the regionalization reduces the number of stations for analysis, important observations were made based on this analysis. It is also reasonable to assume that wetland functions could change with changes in the seasons because of the associated changes in climate and land cover. Therefore variability of the influence of wetlands were evaluated for the different seasons.

The major conclusions of the study follow. It should be mentioned that for the sake of brevity, the conclusions for peakflow were made on the basis of the results for peakflow to average precipitation ratio only. Even though the patterns are similar, the peakflow to average precipitation parameter showed the most consistent result among the three peakflow ratios. The conclusions for low flow were made on the basis of the results for Q_{95} , since the total number of zero values associated with it was less than that with Q_{99} .

1. Peakflow decreases as the percentage of wetland areas increases in the watershed. For the state as a whole, including the 30 stations, the peakflow parameter decreased by an

average of 3.7 percent for one percent increase in wetland area. The percent change in the peakflow parameter varied from a decrease of 8.7 percent for central Illinois to an increase of 1.5 percent in southern Illinois during the fall season. The influence of wetlands on peakflow is more pronounced in northern and central Illinois than in southern Illinois. Seasonally, wetland acreage influences peakflow more significantly in the fall season than the other seasons.

2. Floodflow volume decreases to a lesser extent as compared to peakflow, as wetland percentage increases. For the whole state, the floodflow volume parameter decreased by an average of 1.4 percent for one percent increase in wetland area. The percent change in the floodflow parameter varied from a decrease of 6.9 percent for northern and central Illinois to an increase of 4.4 percent in southern Illinois during the fall season. The influence of wetland acreage on floodflow volume is more pronounced in central and northern Illinois than in southern Illinois. Seasonally, wetland acreage influences floodflow volume more during fall than the other seasons.
3. Low flows increased with increasing wetland acreage in the watershed. For the whole state, the low-flow parameter increased by an average of 7.9 percent for one percent increase in wetland area. The percent change in the low-flow parameter varied from an increase of 22 percent in southern Illinois to a decrease of 4.7 in central Illinois during summer. The influence of wetland acreage on low flow is more pronounced in southern and northern Illinois than in central Illinois. Seasonally, the influence of wetland acreage on low flow is more significant during summer, fall, and winter and less significant during spring.

Limitations of the database should be remembered in generalizing the results of this study. The first limitation is the limited database used in the regional analysis: 11 stations for southern Illinois, 8 stations for central Illinois, and 11 stations for northern Illinois. For Illinois as a whole, data were for 30 stations. Therefore, results and conclusions for the whole state may be considered more definitive.

Another weakness of the database is the skewed distribution of wetland percentages in the watersheds analyzed. Although wetland percentage ranged from 0.2 to 13.7 percent, 11 watersheds (37 percent) had percentages of wetlands less than or equal to 2 percent, 19 watersheds (63 percent) had percentages of wetlands less than or equal to 5 percent, while 28 watersheds (93 percent) had percentages of wetlands less than or equal to 10 percent. Thus, a relatively uniform distribution of wetland percentage was not available. As a result, the conclusions drawn based on the study of these watersheds should be viewed with some caution until the range of percent wetland area is expanded.

The present analysis can be improved by increasing the number of stations for each region to at least 20. This will provide a broader database for each region and the regional and seasonal-regional conclusions will be more reliable. Attempts should also be made to select other watersheds in Illinois and from neighboring states so as to obtain a wider distribution of the percentage of wetlands in the watersheds. This will significantly improve both the scope and reliability of the conclusions from the current study.

REFERENCES

- Bailey, A.D., and T. Bree. 1980. *Effect of Improved Land Drainage of River Floodflows*. Institute of Civil Engineering. Flood Studies Report - Five Years on, London, England, pp. 95-106.
- Bardecki, M.J. 1987. *Cumulative Impacts of Agricultural Land Drainage on Watershed Hydrology*. Proceedings of the National Wetland Symposium: Wetland Hydrology, September 16-18, Chicago, IL. Editors, Jon A. Kusler and G. Brooks, pp. 124-128.
- Brunner, G.W. 1988. *Comparison of Modeling Techniques for Wetland Areas*. Report No. 88-4, The Hydrologic Engineering Center, USACOE, Davis, CA.
- Burke, W. 1968. *Drainage of Blanket Peat at Glenamony*. Proceedings of the Second International Peat Congress. H.M.S.O., 2:809-817, Edinburgh, Scotland.
- Campbell, K.L., and H.P. Johnson. 1975. *Hydrologic Simulation of Watersheds with Artificial Drainage*. Water Resources Research 11(1): 120-126.
- DeBoer, D.W., and H.P. Johnson. 1971. *Simulation of Runoff from Depression Characterized Watersheds*. Transactions of the American Society of Agricultural Engineers 14(4):615-620.
- Demissie, M., N.G. Bhowmik, and J.R. Adams. 1983. *Hydrology, Hydraulics, and Sediment Transport, Kankakee and Iroquois Rivers*. Illinois State Water Survey Report of Investigation 103, Champaign, IL.
- Eggelsmann, R. 1972. *The Water Balance of Low Land Areas in the Coastal Region of FRG*. Hydrology of Marsh Ridden Areas, UNESCO Press, Paris, France, pp. 355-367.

- Eli, R.N., and H.W. Rauch. 1982. *Fluvial Hydrology of Wetlands in Preston County, West Virginia*. Symposium on Wetlands of the Unglaciaded Appalachian Region. West Virginia University, Morgantown, WV, pp. 11-28.
- Haan, C.T., and H.P. Johnson. 1968. *Hydraulic Model of Runoff from Depressional Areas*. Transactions of the American Society of Agricultural Engineers 11:364-367, Ames, IA.
- Irwin, R.W., and H.R. Whiteley. 1983. *Effect of Land Drainage on Streamflow*. Canadian Water Resources Journal 8(2):88-103.
- Kloet, L. 1971. *Effects of Drainage on Runoff and Flooding within Pembina River Basins: North Dakota - Manitoba*. Bureau of Sport Fisheries and Wildlife, Bismarck, ND.
- McCubbin, G.A. 1938. *Agricultural Drainage in Southwestern Ontario - Its Effect on Stream Discharge*. Engineering Journal 21(2):66-70, Ontario, Canada.
- McGill, H.N., and A.C. Bennet. 1971. *Effects of Surface Drainage on Streamflow*. American Society of Agricultural Engineers, Paper 71-712.
- Moklyak, V.I., G.B. Kubyshkin, and G.N. Karkutsiev. 1972. *The Effects of Drainage Works on Streamflow*. Hydrology of Marsh-Ridden Areas, UNESCO Press, Paris, France, pp. 439-446.
- Moore, I.D., and C.L. Larson. 1979. *Effects of Drainage Projects on Surface Runoff from Small Depressional Watersheds in the North Central Region*, Water Resources Research Center, Bulletin 99, University of Minnesota, Minneapolis, MN.

- Novitzki, R.P. 1982. *Hydrology of Wisconsin's Wetlands*. Information Circular 90, U.S. Geological Survey, Madison, WI.
- Ogawa, H., and J.W. Male. 1983. *The Flood Mitigation Potential of Inland Wetlands*. Water Resources Research Center Report 138, University of Massachusetts, Amherst.
- O'Kelly, J.J. 1955. *The Employment of Unit Hydrographs to Determine the Flows of Irish Arterial Drainage Channels*. Proceedings of the Institute of Civil Engineers 4:365-444, London, England.
- Prior, C.H., and J.H. Hess. 1961. *Floods in Minnesota, Magnitude and Frequency*. Minnesota Department of Conservation, Division of Waters Bulletin No. 12.
- Skaggs, R.W., and R.G. Broadhead. 1982. *Drainage Strategies and Peak Floodflows*. Summer Meeting of the American Society of Agricultural Engineers at University of Wisconsin, Madison, WI, June 27-30, 1982, Paper No. 82-2054.