Living With The Lakes: Challenges and Opportunities

Annex D
The Great Lakes Ecosystem Perspective: Implications for Water Levels Management

A satellite view
of the Great Lakes
Photo courtesy of
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Environment Canada.

LIVING WITH THE LAKES:

CHALLENGES

AND

OPPORTUNITIES

ANNEX D

THE GREAT LAKES ECOSYSTEM PERSPECTIVE: IMPLICATIONS FOR WATER LEVELS MANAGEMENT

PREPARED BY FUNCTIONAL GROUP 5
FOR THE PROJECT MANAGEMENT TEAM

International Joint Commission
Water Levels Reference Study

JUNE, 1989

PHASE 1 REPORT OUTLINE
IJC FLUCTUATING WATER LEVELS STUDY

MAIN REPORT

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ANNEX B - ENVIRONMENTAL FEATURES, PROCESSES AND IMPACTS: AN ECOSYSTEM PERSPECTIVE ON THE GREAT LAKES - ST. LAWRENCE RIVER SYSTEM

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THE GREAT LAKES ECOSYSTEM PERSPECTIVE: IMPLICATIONS FOR WATER LEVELS MANAGEMENT

OVERVIEW AND RECOMMENDATIONS

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EXECUTIVE SUMMARY

Functional Group 5 was given the responsibility for developing a whole-system perspective for addressing the issues associated with fluctuating levels and flows in the Great Lakes-St. Lawrence River System. Such a perspective was seen as a means of enhancing understanding of the context for mediating the hydrological, ecological, human and institutional forces relevant to alleviating the adverse consequences of fluctuating water levels in the Great Lakes - St. Lawrence River Basin.

In the course of its work the group explored the linkages between and within four major clusters of issues:

1. Climate, hydrology and hydraulics as they relate to water levels and flows;

2. The "natural" ecology of the system with a focus on coastal zone processes, habitats and biota;

3. Human activities as related to various socio-economic interests that are affected by fluctuations;

4. Governance processes, in particular as they pertain to managing the issues associated with fluctuations in levels and flows.

Levels issues are closely linked to various social and natural factors, including ecosystem integrity, water quality, shoreline development, regional economic development, governance processes and the like. Level issues are systemic in nature and they are constantly changing in relation to changing conditions, changing values and changing institutions. They are also multifaceted. Fluctuating levels and flows affect interests in different and often opposing ways and actions to alleviate the adverse consequences of fluctuating waters will almost inevitably result in both positive and negative effects depending on particular interests and their perceptions. Over time there are many instances where well-intentioned actions could well increase the very problems that they are supposed to resolve. It is, in fact unrealistic to think in terms of one-time solutions. Rather the inescapable conclusion is that issues related to levels and flows must be managed over time and, that ideally, such a management process should take place within a policy and institutional framework that is sensitive to the systemic dimensions of the issues involved.

Viewed in this context it is clear that "engineering solutions" are not sufficient in and of themselves, although they could constitute elements in an overall strategy for managing levels issues over time. Clearly there is a need for governments to explore and develop the "common ground" as well as outline an overall plan that will help them manage levels issues in a more systemic manner.

More specifically, Functional Group 5 concludes that there is a need for the governments of Canada and the United States to build upon previous knowledge, experience and areas of agreement, with a view to:

1. Developing a general Agreement on principles to guide in managing issues associated with levels and flows in the Great Lakes - St. Lawrence River System.

2. Developing an overall strategy for deploying measures and selecting and implementing a range of actions to help alleviate the adverse consequences of fluctuating levels and flows.

3. Assessing governance arrangements with the intention of identifying needs and opportunities for institutional innovations related to managing lake levels issues.

These three areas represent important prerequisites in the effective ongoing management of level-related problems and, in the view of Functional Group 5, they should thus constitute major components of Phase II of the study.

FOREWORD

Record high levels on the Great Lakes in 1986 followed a long history of significant fluctuations in levels with adverse consequences for people living and working around the lakes. Immediate concerns about high levels together with this historical pattern led to a "Reference" by the governments of the United States and Canada to the International Joint Commission. The Commission was asked to examine and report upon methods of alleviating the adverse consequence of fluctuating water levels in the Great Lakes St. Lawrence Basins. The study was to include an assessment of the current situation, a review and revision of the previous studies and a comparative analysis of alternate measures for dealing with problems caused by fluctuations. These measures were to include different land use and shoreline management practices as well as the lake level regulation schemes.

Five functional groups were formed under the umbrella of the larger study undertaken by the Commission in response to the Reference. Three of these addressed specific aspects of the levels problem while a fourth dealt with communications and public participation. A fifth group, Functional Group 5, was formed to consider problems related to fluctuating levels from the standpoint of the overall system, integrating across these several specific subareas. Such a whole-system perspective was developed as a means of enhancing understanding of the context for considering the human, hydrological, ecological, and institutional factors relevant to the issue of alleviating the adverse consequences of fluctuating water levels in the Great Lakes St. Lawrence River Eco-system. The Group was multidisciplinary, consisting of experts in cybernetics, ecology, engineering, environmental studies, hyrdology, management, political science, sociology, and systems analysis.

The following is a synthesis of the principal insights, concepts, and conclusions that have resulted from the Phase I work of Functional Group 5. In this synthesis, we have attempted to provide enough background so that our findings and recommendations are clear but we make no attempt to offer complete, detailed rationale in this document. Much of the necessary explanatory and supporting material is contained in Appendices 2 and 3, and in the proceedings of our workshop on "Alternative Policies and Means for Governance" to which many leading authorities in the field have contributed.

We believe our conclusions and recommendations have considerable relevance for the long term management of issues associated with fluctuating levels and flows in the Great Lakes St. Lawrence River system. We also see them as having important implications for the overall direction and specific tasks appropriate to Phase II of the levels Reference study.

SECTION 1 - INTRODUCTION: TAKING A SYSTEMS PERSPECTIVE

1.1 Why A Systems Approach

The Great Lakes-St. Lawrence Basin is a complex dynamic system in which many elements - hydrological, climatic, ecological, social, economic and political -- interact. The systemic nature of the many interactions involving levels and flows of water, human activities and various non-man made components of the basin's ecology, must be recognized if effective management policies are to be developed. Taking a whole system's perspective, or a systems approach, is thus essential in approaching the issue of alleviating the adverse consequences of fluctuating water levels.

There are a number of fundamental ideas which are brought into focus by the "System Approach." Briefly, they include the following:

- The notion of "whole-system:" The idea that there are aspects of the whole that are not captured by any of the parts alone.
- The notion of connectivity: Emphasizing a high level of interconnectiveness and the mutual effects of parts on each other and on the whole.
- The notions of complexity and irreducibility: Namely, that complexity is a genuine property and that complex systems cannot be handled effectively by reduction to simple parts.
- Finally, the notion of synergy: The emergence, through interactions, of novel properties that are not inherent to any specific single part, and the in-principle unpredictability of the whole from the behavior of the parts.

By referring to the Great Lakes as a system we mean to emphasize the very fact that the basin, as the context for any purposeful intervention, comprises many different elements and that those elements are interconnected and interact with each other, over time, in different, complex ways. These interactions give rise to behavior that is characteristic of that total system and cannot be simply and linearly extrapolated from an analysis of its individual parts. Measures introduced into the system will affect this pattern of interactions in ways that cannot be anticipated by looking at single elements in isolation. A reductionist approach in analysis and in the development of policy is not likely to yield effective long term results. The complex dynamic nature of the context must be taken into account yet it ought not paralyze action. The emphasis on complexity should not be construed as an argument against action; rather, it ought to highlight the need to recognize the consequences of proposed actions on the whole system before specific actions are implemented.

The need for a comprehensive ecosystem approach was recognized in previous IJC documents and, in fact, the Great Lakes Water Quality Agreement of 1978 commits to a concept of ecosystem management defining the Great Lakes ecosystem as "the interacting components, of air, land, water and living organisms, including man, within the drainage basin of the St. Lawrence River...," thus acknowledging the interdependence and inseparability of the system's component parts. Much remains to be done, however, if this recognition is to be translated into coherent policies and an effective management practice.

1.2 Understanding the System As A Guide to Action

Problems concerning basin wide management, including water quality and pollution, shoreline development, navigation, water diversion and effects of fluctuations in levels and flows, interact and affect each other in a number of important ways.

Many factors are involved which together take part in a vast and complex web of linkages forming important feed-back relationships. These form underlying structural patterns, which work to amplify or resist changes in the system. It is, therefore, not always easy to foresee overall effects of specific interventions and an understanding of the system as a whole as well as its internal dynamics is critically important.

In developing a whole system view of the Great Lakes-St. Lawrence basin, we have chosen to resolve the whole into four interacting major components or clusters of issue. These consisted of the following:

- Climate, hydrology and hydraulics as they relate to water levels and flows.
- The "natural" ecology of the system with a focus on coastal zone processes, habitats and biota.
- Human activities as related to various socio-economic interests that are affected by fluctuations.
- Governance processes, in particular as they pertain to managing the issues associated with fluctuations in levels and flows.

Each of these interacting components is an important part of the whole system, and each represents an exceedingly complex system in its own right. Because of the webs of interaction within and between them, potential intervariation are likely to produce direct as well as indirect impacts of various kinds. From a management viewpoint, perhaps the most significant statement that could be made in facing the challenge of this complexity, is that neither the system as a whole nor its major component parts, are subject to complete human control.

In principle, two systemic aspects are enormously important for the development of effective policies for basin-wide management. The first, as mentioned earlier, has to do with a comprehensive whole-system perspective. Only the recognition and understanding of the complex variety of interacting variables and the ways they affect one another can yield a sound basis for guiding interventions. The second aspect has to do with specific ways in which particular components of the system interact: The nature of their dynamics, underlying structure, and effect over time. This is important since, in some cases, the underlying dynamics of the forces involved may produce results which are contrary to intended interventions.

A typical example of such a case is illustrated by the interaction of damage, implementation of protective structures, and shoreline development. In such a typical case, adverse effects of fluctuating water levels may bring about a demand for implementing protective structures. When these are put in place, they may alleviate some of the adverse effects. At the same time, however, they may cause a sense of security that will increase the intensity of shoreline development thus increasing vulnerability and potentially amplifying future adverse effects.

There are a number of circular loops, such as the one just described, operating throughout the system. As a guide to effective action they are important to identify and understand, since the particular way in which these loops interact over time drives the actual behavior of the system, some aspects of which may be especially significant; in this case, unintended consequences of implementing protective structures. The example cited does not suggest that protective structures be avoided in all cases, but rather that, when they are built, they should be accompanied by other measures, such as land use controls, designed to keep adverse consequences from escalating and offsetting the intended benefits.

In its work, Functional Group 5 has produced a general system representation identifying and focusing on some of the key underlying interaction that are relevant from the view point of managing level related issues. Much of the pertinent material is reproduced in Appendices D-2 and D-3. The following sections will focus on highlighting our conclusions and recommendations.

SECTION 2 - HIGHLIGHTS OF MAJOR CONSIDERATIONS

2.1 The Systemic Nature of The Problem

2.1.1 The Nature of the Problem

Issues associated with fluctuations in levels and flows in the Great Lakes-St. Lawrence River Basin are systemic in nature and, therefore, cannot be adequately addressed as a single or discrete problem. Similarly, levels change. Interests' preferences and investments change. Attitudes, values, and institutions change. Levels issues, therefore, cannot be solved once and for all. Management of levels issues must be viewed as an enduring process, not a search for a discrete, one-time solution. They must be managed overtime.

Levels are inseparable from many other social and natural forces and issues, including ecosystem integrity, shoreline and regional economic development, water quality, politics, and the like. Management of levels issues, therefore, must be sensitive to and consistent with management of many other issues. And it should be carried out within a policy and institutional framework that is mindfull of the systemic nature of the problem.

Levels issues are multifaceted. At any site, for any level, hydrological, geomorphological, land use, ecological, economic, demographic, political and legal considerations, and other types of forces and considerations will come to bear. Measures designed to change only one or a few of these will inevitably have effects on others. Measures designed without attention to their interactions with other phenomena or to the incentives and pressures created by the measures themselves could have adverse effects and may actually increase the very problem they were supposed to resolve. Such secondary effects have to be addressed. Measures for managing and techniques for analyzing levels issues, therefore, need to be multifaceted and designed to take into account their own long-term, secondary, and indirect effects.

2.1.2 The Nature of Measures

In principle, measures can be directed at the physical components of the system or they can be applied to the patterns of human activities that exacerbate the potential for adverse consequences. The nature of levels issues requires consideration of both.

2.1.3 Interests and Issues

At the most fundamental level, the adverse consequences of fluctuating levels are a function of people in interaction with hydrology. Managing levels issues means managing human activities as well as water.

Different patterns of preferences, costs, benefits, and risks to interests will be associated with different levels and flows at different times and at different locations. The consequences of fluctuations may be perceived by any particular group to be beneficial or adverse or both, depending on the uses made of the ecosystem by that group at that time. Hence, managing levels issues also means managing the process of allocating costs, benefits, and risks across groups.

Both fluctuating levels and flows and the measures that might be taken to address their consequences will inevitably lead to conflicts over how the system is to be used and managed and how costs, benefits, and access are to be allocated. These conflicts will include pressure upon valued ecosystem components and attributes (e.g., wetlands, wildlife, integrity, quality, diversity, health, and productive capacity) that need to be safeguarded. Conflicts themselves are an adverse consequence and constrain the ability to select and implement measures. Managing these conflicts to reduce their potential negative effects is an important part of dealing with levels issues.

Increased physical capacity to regulate levels and flows increases regulators' responsibility to allocate costs and benefits to different interests and different parts of the system and is likely to lead to conflicting pressures from interests. Increased technical capacity to physically regulate levels and flows is likely to outstrip the political capacity to make these allocations in a manner that is seen as being fair and equitable to all interests. Improved governance capabilities will have to accompany increased technical water management capabilities.

Potential for conflict, displacement of fluctuations, costs, questions of who will pay, and other issues make it unwise to depend on strategies that emphasize only control of fluctuations, even if these are technically feasible. These considerations reinforce the need for a multifaceted approach to the selection and implementation of measures.

2.2 Geophysical, Hydrological, and Ecological Dimensions

2.2.1 Hydrology and Water Supply

Net basin supplies of water to the Great Lakes-St. Lawrence River Basin Ecosystem have always fluctuated and will continue to fluctuate, primarily because of fluctuations in precipitation and evaporation. Fluctuations in net basin supplies are superimposed on prior basin hydrologic conditions and translate into storage and fluctuations in levels and flows throughout the system.

Climate change could have a significant effect on future levels and flows in the Great Lakes-St. Lawrence River System. Current speculation suggests that net supplies of water to the basin will, over the long term, be reduced and that levels and flows in the system will decline. Low flows and low levels in tributaries may become a much more pressing problem than high water levels.

Regulatory works to modify levels, flows, and fluctuations in one part of the system invariably lead to effects on levels, flows, and fluctuations in other parts of the system. Limiting fluctuations in one part of the system will lead to increased fluctuations elsewhere.

Full regulation would require a capacity to import and export large quantities of water to and from the system, which puts a practical limitation on the extent of possible control. Other considerations, including the inability to predict future climatic conditions and future supplies, as well as the time delays in the system, further limit the ability to control static water levels. In addition, static levels cannot be altered enough to overcome the adverse effects of major storm events.

2.2.2 Erosion and Flooding

Coastal-zone erosion, sediment transport, and sediment deposition processes are linked to fluctuations, although there is increasing evidence that these linkages are much less direct than formerly inferred. The long-term rate of coastal-zone erosion in most erodible reaches does not appear to be significantly influenced by water-level fluctuations.

Coastal-zone erosion is directly influenced by wave energy and local geology. Hence, actions have to be designed to take site-specific conditions into account.

Coastal-zone flooding is associated with static water levels, but the effects of static levels are, in most instances, of relatively minor importance compared to the flooding and wave-impact damage associated with storm events. Susceptibility to storm events is highly dependent on local conditions. Again, actions have to be designed to take site-specific conditions into account.

2.2.3 Wetlands

Coastal-zone ecosystems have evolved in the presence of fluctuations in levels and flows and many have become dependent on such fluctuations. Erosion and flood-related processes are a natural part of these ecosystems and are essential to their integrity, quality, resilience, diversity, and productivity.

Wetlands and the plant and animal communities that are part of these ecosystems are particularly important and valued components of the coastal zone. Their beneficial effects extend long distances inland and offshore. Wetlands provide a rich and varied habitat for fish, plant, and wildlife species and play an important role in modulating flows and cycling matter and energy in the whole Great Lakes-St. Lawrence River Basin. An additional function of wetlands, quite relevant to levels issues, is their ability to buffer fluctuations.

Individual wetlands will, over the short term, decrease or increase in area in response to changes in static water levels. Over the long term, the overall integrity and health of most wetlands is dependent on the continuation of event-related, seasonal, and long-term fluctuations that approximate those which prevailed while the wetland ecosystem was evolving.

2.2.4 Water Quality/Quantity Linkages

Water quantity and water quality are inextricably linked; fluctuations in levels and flows have very important relationships to water quality. In particular, low levels and flows make water quality preservation more difficult because of, for example, reduced ability to dilute sewage and increased dredging activity when levels are low. Because of this link, managing the issues associated with water quantity demands sensitivity to potential effects on water quality.

2.2.5 Hydrology and Human Activity

Neither the system as a whole nor its major component parts are subject to complete human control. To date, the storage and fluctuations in the system are largely defined by nature. Man-made interventions -- including diversions, consumptive uses, and land-use practices -- have all had relatively minor effects on levels and flows in the basin as a whole.

There is need for increased understanding of the hydrology of the lakes. Public debate is often prolonged on issues that are technical in nature. These should be addressed in technical fora, but their conclusions should be publicly available in an readily understandable form. Research on levels-related Great Lakes issues needs to be strengthened. Communication of up-to-date information also needs to be improved so that public debate is conducted on a better informed basis.

Much information already exists that is effectively inaccessible to decision makers. State and, especially, local decision makers need better access to the best available scientific and technical information.

2.3 Agreements, Strategies for Deploying Measures, and Governance Considerations

2.3.1 Agreements

Existing agreements reveal considerable consensus as to the direction to be taken in maintaining and enhancing the integrity of the Great Lakes-St. Lawrence River System. This consensus is reflected in the Boundary Waters Treaty, the Great Lakes Water Quality Agreement, the Great Lakes Charter, the Great Lakes Toxic Substances Control Agreement, and in other regional agreements.

There are many similarities in the policies of the two federal governments. However, any absence or perceived absence of clear and consistent signals from the two federal governments makes it difficult for other levels of government to develop their plans and programs in an informed and responsible manner.

A joint statement or communique from the two federal governments that clarifies overall federal intentions would set direction and provide a framework for informed and responsible decisions and actions. The two federal governments would be making a significant contribution if the joint statement included a clearly articulated vision of the desired future of the Great Lakes- St. Lawrence River Basin Ecosystem.

2.3.2 Strategies for Deploying Measures

In principle, measures to deal with fluctuating levels and flows can be viewed from two fundamentally different perspectives: Controlling the natural system or influencing human activity. While advocates of these two approaches have often seen them as being at odds, the two approaches ought to be regarded, in fact, as important components of a coherent strategy.

Generally speaking, any publicly funded government policy, program, or project that modifies fluctuations in levels and flows or that reduces the impact of these fluctuations will reduce the perceived risk of investment in structures that are susceptible to fluctuations over the long term. Investments will likely lead to greater overall vulnerability unless balanced by measures designed to prevent vulnerability.

Development of measures is likely to be more effective if it is driven by an overall strategy or a general plan. Consistent with binational agreement on long term objectives, such a strategy would articulate conditions under which various measures and combinations of measures could best be applied. It would also deal with issues of priorities, sequencing of implementation, and resource allocation encouraging a consistent concerted effort rather than sporadic and piecemeal response.

It is not enough to consider the impact of a particular proposal or measure on existing interests. Because of the dynamic nature of human activity and their adaptive nature, future responses may counteract or even negate the intent behind a particular measure. Therefore, it is important that likely future human responses to those measures be thoroughly explored.

2.3.3 Governance

The distribution of governance jurisdiction and responsibility for managing lake levels issues among federal, state/provincial, and local governments is complex and often confusing.

The two federal governments, either directly or through the International Joint Commission, have special responsibilities with respect to managing levels and flows. The states and provinces have the major responsibilities for the management of most of the human activities that are influenced by fluctuations in levels and flows.

In recent years there has been a transfer of responsibility and costs from the federal levels of government to the state and provincial levels. Because of this, there is a greater need for federal governments to articulate shared policies, principles, and guidelines that will enable the state and provincial governments to approach their responsibilities in an informed and responsible manner.

State/provincial and local municipalities are becoming ever more involved in Great Lakes regional issues. Also, many nongovernmental organizations (such as citizen interest groups and industry groups) are actively trying to influence the region's future. There are, therefore, ever more centers for initiative and responsibility for governing the Great Lakes St. Lawrence system. The need is to capture the diversity of initiative and decentralized responsibility, but to do so in a way that allows all groups to work toward common goals and priorities so that the sum of the activity is consistent, rational, and constructive.

2.3.4 Public Understanding

Individual interests have very different preferences with respect to levels and flows. Preferences vary dramatically both within and between interest groups. The asset and investment profiles (including nonmonetary) of individual interests lead them to exert pressure on government for measures that will protect and enhance their assets and investments, often at the expense of others.

Individual interests generally bring pressure on governments to allocate public works, public programs, and public funds to protect or enhance their personal, private interests. Both high and low levels result in such public pressure. It will remain difficult to accommodate all their competing demands.

Public reactions are driven by perceptions and understanding. So long as many interests believe that the federal governments might be prepared to authorize major public projects for the further regulation of water levels and flows in the Great Lakes-St. Lawrence River System, they will not be receptive to other alternatives.

Unless the state of knowledge and public awareness is changed through the actions of government and voluntary groups, it is almost inevitable that interests will continue to make poorly informed decisions about investments in assets that are vulnerable to fluctuations. Their resulting vulnerability will, in turn, cause them to continue to bring more pressure on governments for further regulation of levels and flows in the system and for government financial assistance to compensate for damages caused by fluctuating water levels and flows. It is in the governments' interest to promote the development of information and understanding that will encourage interests to make informed, responsible decisions about the risks they take in using and building near the lakes.

SECTION 3 - RECOMMENDATIONS

3.1 Recommendations Pertaining to Information, Public Understanding, and Involvement

3.1.1 Findings

Policy and planning for the management of lake-levels issues are sometimes hampered by the lack of reliable scientific information, at times by failure to disseminate existing information to relevant decision makers, and, at times, by public misunderstanding. Furthermore, resources for public information and education, although often well-prepared and of good quality, fall short of their full potential effectiveness because they do not reach enough of the public and they are not incorporated into the substance of formal education.

There is a trend toward more local and nongovernmental involvement in lake-levels issues, which is resulting in more decentralized centers for initiative and responsibility. There is also a growing sense that the Basin is a shared bioregion. Together these phenomena create a need for more coordination, cooperation, and sharing of information. The energy and momentum for action on Great Lakes issues could be enhanced through closer cooperation and coordinative relationships between nongovernmental organizations and the responsible authorities. Such relationships should be open, public, and fully disclosed.

3.1.2 Recommendations

It is recommended:

1. That the binational authorities place increased emphasis on comprehensive, integrated monitoring of a range of key indicators of conditions and trends in the Great Lakes Basin ecosystem.

2. That the binational authorities make provision for the periodic publication of information derived from monitoring and other pertinent scientific data contributory to public and official understanding of the meaning of developments in the Great Lakes-St. Lawrence Basin. It is essential that reports be in language intelligible to the public and adaptable to use in schools at secondary and college levels.

3. That currently produced International Joint Commission periodic reports (e.g., water quality reports) be expanded and recast so that they encompass a more complete and integrated view of the phenomena relevant

to maintaining and enhancing the ecosystem. In other words, a "State of the Lakes" report focused on conditions and trends across the whole the Great Lakes-St. Lawrence ecosystem should be produced. It would address water quality, water quantity, whole ecosystem, regional development, socioeconomic, demographic, and other phenomena.

4(a). That the federal governments, perhaps through the International Joint Commission, enlarge and extend existing capabilities for developing and disseminating levels-oriented information. This should be done in a manner that is, and is perceived by the public to be, independent, competent, and representative of the full range of scientific, technical and public opinion. This capability would include the development of information in areas where it is currently lacking, the dissemination of information for general education purposes, and the provision of expertise to local governance bodies seeking assistance in managing their relationships to the Basin. In the view of Functional Group 5, it might be preferable to extend the responsibilities of an existing technical advisory body to include these functions rather than create a new body.

4(b). The technical/scientific capability would allow for systematic assessment and provision of information about, for example:

- Hydrologic, geophysical, and climatic phenomena.
- Levels forecasts and their reliability.
- Land-use management strategies and standards, including relevant experiences from other regions.
- Existing patterns of interests' vulnerabilities to water fluctuations, especially with regard to how various measures and government activities affect patterns of vulnerability.
- Social and psychological factors influencing how individuals and interests respond to fluctuations in levels and flows and to measures taken to alleviate the adverse consequences of fluctuations.
- Other factors influencing individual decision making regarding uses of the lakes and investments in lakeside facilities.

4(c). The technical/scientific capability would allow for development and refinement of a set of policy models to help assess the implications of future actions, making available scientific information accessible both for educational purposes and in a form that would assist decision makers in assessing the costs and benefits of various actions. These models could include, for example, hydrology, erosion, and wetlands models.

5. That the occasional fora in which representatives of nongovernmental organizations and concerned individuals meet with official representatives of governmental jurisdictions regarding ecosystem matters (including coastal-zone management, remedial action implementation, and protective structures) be regularized and scheduled periodically, with interim arrangements to maintain liaison. The International Joint Commission could be a sponsoring authority, conducting careful advance planning and ensuring representation from all concerned sectors of the public and from the state, provincial, and local authorities that act directly upon many Great Lakes issues. This recommendation has budgetary implications not only for the International Joint Commission but for participating agencies, public and private.

6. That, to effectuate the foregoing recommendations, a general procedural plan for continuing communication, consultation and public involvement be developed and put into effect. Such an arrangement would facilitate the coordinative action needed for multijurisdictional management in the basin.

3.2 Recommendations Pertaining to Agreements, Strategies for Deploying Measures, and Governance Considerations

3.2.1 Findings

Agreements incorporating general and specific objectives and principles for guiding action could provide powerful tools for managing the Great Lakes-St. Lawrence System. Defining shared goals and objectives could help motivate, reinforce, and coordinate effort. The diversity of interacting interests, issues, jurisdictions, and problems in the Great Lakes-St. Lawrence Basin make coordinated action especially difficult to achieve but also especially critical. In addition, after decades of relatively <u>ad hoc</u> responses to levels-related environmental exigencies, the time has come when a review and consolidation of policies and institutional arrangements and development of strategies for deploying measures are needed in order to meet commitments already made by the two federal governments toward the future of the Great Lakes-St. Lawrence system.

The following recommendations go beyond making the existing arrangements work better. They highlight the need for new agreements and institutional innovations designed to produce a more comprehensive and integrated system for governance in the Great Lakes-St. Lawrence Basin.

3.2.2 Recommendations

It is recommended:

7(a). That a General Agreement for the protection, restoration, and management of the Great Lakes-St. Lawrence River Basin ecosystem be negotiated by the responsible parties. Such an agreement could consolidate and bring clarity and consistency to the many instruments for policy and management relating to the waters and their biota, including human activities and regional development in the Basin. It should articulate an overall strategy for deploying measures and should include guidelines for decisions pertaining to protective structures, control structures, "adaptive" measures such as land-use planning, protection of wetlands and coastlines, and restoration of degraded areas.

7(b). That the General Agreement build upon existing agreements such as the Boundary Waters Treaty of 1909, the 1954 Great Lakes Fishery Convention, the Water Quality Agreement of 1978, as amended in 1987, the IJC report of 1985 on Great Lakes Diversions and Consumptive Uses, the IJC interim report of 1988 on High Water Levels, and existing localized policies and agreements pertaining to channels, levels, and flows. It could also incorporate findings and principles that emerge from the studies carried out pursuant to the 1986 IJC Reference on fluctuations in water-levels in the Great Lakes-St. Lawrence River system.

7(c). That the General Agreement be negotiated as a formal document, one that reaffirms, complements, and clarifies the Boundary Waters Treaty of 1909 as it pertains to the Great Lakes-St. Lawrence Basin ecosystem and that also encompasses the essence of the Water Quality Agreement of 1978 as amended in 1987.

8. That, to lay the foundation for a General Agreement, the federal governments, in cooperation with the provinces and states and other such entities as appropriate, convene a basin-wide binational conference on the future of the Great Lakes-St. Lawrence River ecosystem. The conference could be held in 1992. The agenda and details for the conference would be the responsibility of a Preparatory Working Group.

9. That, in order to establish a more integrated advisory function, it may be time to reconsider the Commission's advisory arrangements, many of which have evolved incrementally in response to specific needs.

10. That existing governance mechanisms and institutional arrangements ought to be assessed with a view toward necessary innovations.

11(a). That, pending ratification of a General Agreement, the respective federal governments not defer efforts toward other agreements pertinent to the Great Lakes-St. Lawrence Basin, including interim agreements, that are consistent with already-accepted ecosystem principles.

11(b). That, pending ratification of a General Agreement, the respective federal governments not undertake commitments toward planning, funding, or constructing major public works to control levels and flows in the Great Lakes-St. Lawrence watershed.

12. That, in general, new measures for alleviating the adverse consequences of fluctuating water levels should be funded according to a "primary beneficiary pays" philosophy. For example, where protective works are strengthened or extended for local or private interests only, the costs of such structures, including the costs of mitigation and compensation, should be borne by the immediate beneficiaries rather than distributed among the general taxpaying public.

3.3 Recommendations Pertaining to Phase II of the Lake-Levels Refernce

3.3.1 Findings

The principal task of Phase II would be to set in motion the actions needed to achieve a more effective response to water levels issues within the broader context of governance for the Great Lakes-St. Lawrence Basin ecosystem. Specifically, activities ought to focus on: Increasing and refining understanding about critical aspects of the system; developing elements of a framework agreement; developing a strategy for deploying measures; and developing recommendations about governance and institutional arrangements.

3.3.2 Recommendations

It is recommended:

13. That a general survey or several methodologically compatible surveys of public understandings, attitudes, values and major factors influencing individuals' and

interests' decisions concerning the Great Lakes-St. Lawrence Basin ecosystem be conducted. Such surveys would reveal the extent to which public understanding of the issues is consistent with the findings and conclusions of technical experts and with the ecosystem assumptions upon which present policies are based. The findings should inform, but not constrain, deliberations antecedent to a General Agreement for the Great Lakes.

14. That activities are continued to ensure systematic assessment and provision of information relevant to designing, implementing, and understanding the impacts of measures. For example, information should be developed about:

   - Hydrologic, geophysical, and climatic phenomena.
   - Levels forecasts and their reliability.
   - Land-use management strategies and standards, including relevant experiences from other regions.
   - Existing patterns of interests' vulnerabilities to water fluctuations, especially with regard to how various measures and government activities affect patterns of vulnerability.
   - Social and psychological factors influencing how individuals and interests respond to fluctuations in levels and flows and to measures taken to alleviate the adverse consequences of fluctuations.
   - Other factors influencing individual decision making regarding uses of the lakes and investments in lakeside facilities.

15(a). That one of the major products of Phase II of the study be a report on the State of the Great Lakes-St. Lawrence River System. This report will be broad in scope and provide an integrated view of phenomena relevant to rehabilitating, maintaining, and enhancing the system, and encompass water quality, water quantity, whole ecosystems, regional development, socio-economic, demographic and other phenomena.

15(b). That the report be designed to provide one important element in the public information program that is to be developed under the August 1, 1986 Reference and that it be an important product to be prepared for the proposed conference on the future of the Great Lakes-St. Lawrence River System.

16. That, as part of Phase II of the study, the International Joint Commission enlarge and extend its existing capability for developing and disseminating levels-oriented information. This capability would include the development of information in areas where it is currently lacking and the dissemination of information for general education purposes.

17. That the following activities be included in Phase II:

    - Articulating the elements of a General Agreement on principles for guiding the future development of the region.

    - Developing the elements of a strategy for selecting and deploying measures.

    - Assessing governance arrangements with the intention of identifying needs and opportunities for managing lake-levels issues.

18. That the International Joint Commission convene a Preparatory Working Group which, in conjunction with all the preceding suggested activities would commence the preparatory work for the conference on the Great Lakes- St. Lawrence Basin ecosystems. The Preparatory Working Group will:

    - Prepare background documents and working papers. In particular, a document should be prepared that identifies relevant principles for ecosystem management that have already achieved some level of acceptance and are working in the Basin (i.e., principles drawn from the Stockholm Conference, the World Conservation Strategy, the Brundtland Report, the Great Lakes Water Quality Agreements, and the Great Lakes Charter).

    - Hold interviews, meetings, and public hearings to identify major options, identify and resolve substantive disagreements, and develop support for a draft agreement prior to the conference itself. The preparatory strategy used by the United Nations prior to the Stockholm Conference could serve as a model.

    Whether or not a General Agreement is ratified at the conference, the preparatory work would be of value in educating and involving both the public and policy makers and in building understanding of and commitment to ecosystem values.

19. That planning for Phase II of the Levels Reference study proceed without interruption.

3.4 Budgetary Considerations

Many of the foregoing recommendations have budgetary implications. They will have to be prioritized and funded.

APPENDIX D-1

GLOSSARY OF TERMS

Functional Group 5

June 14, 1989

GLOSSARY OF TERMS

Definition of Terms:

The following terms have been used extensively in materials developed by members of Functional Group 5.

They are intended to convey the following meaning:

1. Strategy: A general conceptual framework for guiding action based upon a particular purpose and selected means for achieving it.

2. Vulnerability: As used by Functional Group 5 in relation to consequences of water level fluctuations, vulnerability is a concept pertaining to a relative susceptibility of interests to adverse effects. Depending on the choice of level of resolution, the concept of vulnerability could pertain to a spectrum of identification of interests ranging from an individual, to a group of interests (industry) or to some notion of "society as a whole." Vulnerability would thus be sensitive to factors such as concentration of interests in the basin, the type of activity they are engaged in, the assets they employ, including such factors as location and setting, design range of buildings or equipment and the like.

3. System Dynamics: A Simulation modelling methodology developed at M.I.T. for the study of the behavior of complex systems. System Dynamics is based upon the identification of key system variables, the interactions between them and the study of the effects of these interactions over time.

4. Feed back loop: Feed back loops are circular cause and effect relationships dominating some interaction of particular sets of a system's key variables. Feed back loops generally belong to one of two types: "negative feed back loops" which act to maintain the value of a particular variable around a given level, and "positive feed back loops" which act to cause the value of a particular variable to increase or decrease in a self-amplifying manner, and, usually, at a geometric rate.

5. Ecosystem: A subdivision of the Biosphere with boundaries arbitrarily defined according to particular purposes. An ecosystem is a dynamic totality comprised of interacting living and non-living components. The Great Lakes-St. Lawrence River Basin Ecosystem is an example which encompasses the interacting components of sunlight, air, water, soil, plants, and animals (including humans), within the Basin.

6. <u>Ecosystem integrity</u>: "Ecosystem integrity" refers to a state of health, or wholesomeness," of an ecosystem. It encompasses integrated, balanced and self-organizing interactions among its components, with no single component or group of components breaking the bounds of interdependency to singularly dominate the whole.

7. <u>The System Approach</u>: A method of inquiry which complements the classical analytical method of science by emphasizing the concept of "whole systems" and the irreducible properties of whole systems that result from the interactions between individual components.

GLOSSARY OF TERMS
(for the entire Progress Report)

Accretion: Accretion may be either natural or artificial. Natural accretion is the build-up of land, solely by the action of the forces of nature, on a beach by deposition of water or redistribution of material by wind. Artificial accretion is a similar build-up of land by reasons of an act of man, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means.

Action: see "Measures"

Adverse Consequence (a common usage): Some negative implication of fluctuating water levels for a social, economic, environmental or political investment.

Aggregate Sensitivity Model: The link between the visual situation model(s) and the "what if" modelling capability, this step in the analytical process will describe those factors most sensitive or critical in resolving problems caused by fluctuating water levels in the Great Lakes, taking into account the range of measures and stakeholder interests under consideration.

Aggregate Visual Situation Model: A pictorial display linked to an automated information/geographic information system(s) which connects the problems associated with fluctuating water levels with the stakeholders and their interests that are impacted by the problems, with an emphasis on overlapping or interacting relationships.

Agreements: Joint statements among two or more governmental units on (i) criteria (purposes and goals) which should guide basin decision making, (ii) processes of decision making and (iii) authorities of governments to act. Agreements must be formalized in charters, treaties, letters of understanding, etc. Agreements serve to define the boundaries and constraints on choice of measures.

Agricultural Interests: These interests benefit from the services of shore location (fertility and climate), water supply, and indirectly from the transport of grains. This interest class includes all types of farming and production agriculture.

Alternative Dispute Resolution (ADR): Decision making guided by professional experts and based on scientific management principles, but includes interest groups in developing and assessing alternatives and in making tradeoffs between alternatives.

Associated Costs: Costs incurred as a result of implementing a measure. There are two types of associated costs. (1) Cash costs are expenditures required of an interest in order to take advantage of a measure. (2) Opportunity costs are a change in the welfare of an interest as a result of a measure.

Bathymetry: The topography or relief of the lake bottom, as in the measurement of depths of water in oceans, seas and lakes; also information derived from such measurements.

Beneficial Consequence: Some positive implication of fluctuating water levels for a social, economic, environmental or political investment.

Commercial Fishing: Commercial fishing interests use the Great Lakes habitat and shore access services to earn income and sustain a lifestyle from sale of fish and fish products.

Commercial/Industrial: Commercial and industrial interests are those firms whose activities are tied into having a fixed point location along the shoreline and whose net income position is potentially affected by fluctuating lake levels. The interest is made up of a number of diverse businesses that are often represented by specialized trade associations and because of diversity of activities and geographic dispersion may not be uniformly affected by lake level fluctuations.

Compensation: Any expenditure received by an interest to mitigate costs imposed by a measure. Compensation may be in the form of money paid to those affected by an action, or it may involve creating similar conditions to the pre-project state to mitigate effects of the measure.

Connecting Channels: A natural or artificial waterway of perceptible extent, which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. The Detroit River, Lake St. Clair and the St. Clair River comprise the connecting channel between Lake Huron and Lake Erie. Between Lake Superior and Lake Huron, the connecting channel is the St. Marys River.

Consumptive Use: The quantity of water withdrawn or withheld from the Great Lakes and assumed to be lost or otherwise not returned to them, due to evaporation during use, leakage, incorporation into manufactured products or otherwise consumed in various processes.

Control Works: Hydraulic structures (channel improvements, locks, powerhouses, or dams) built to control outflows and levels of a lake or lake system.

Convergent Shores: The phenomena of converging shorelines; such as Saginaw Bay. Water-level fluctuations are exaggerated as shorelines converge.

Criteria: These are evaluative rules on some dimension of concern to one or more interests in the decision making process. Criteria are conceptual but must have operational (measurable in principle) components. Any single criterion can be used to judge the merits of a measure or policy along the dimensions encompassed by the criterion. Criteria are used to judge measures <u>and</u> criteria are used to judge the decision making process (for example, group access to the decision making bodies).

Crustal Movement: The change in level of the earth's surface at a location with respect to another location. Crustal movement is expressed as a differential rate of the change in level over time. This process is still continuing and effects differences in elevations.

Decision by Governments: A choice by government to spend money or to change laws and regulations to implement measures.

Distribution: An assessment of the effectiveness and efficiency of a measure, or combinations of measures, on a basis which considers all of the interests affected by a problem associated with fluctuating water levels. (For consideration within the evaluation framework).

Diurnal Tide: A tide with one high water and one low water in a tidal day.

Diversions: A transfer of water either into the Great Lakes watershed from an adjacent watershed, or vice versa, or from the watershed of one of the Great Lakes into that of another.

Drainage Basin: That part of the surface of the earth that is occupied by a drainage system of rivers and lakes.

Economic Sustainability: The objective of maintaining, at a minimum, the existing level of economic activity within the Great Lakes-St. Lawrence River Basin. Economic growth and development can be realized through greater productivity in the application of existing economic and natural resources so that these goals are not achieved at the expense of environmental, social, and cultural resources of significant value of society.

Ecosystem: The interacting complex of living organisms and their non-living environment. In the context of this IJC study, these concerns relate primarily to biophysical impacts within the coastal zone as a consequence of fluctuating water levels.

Educational and Learning Activities: Activities undertaken through the formal education system, in post-secondary settings, for the media, and in informal, public meetings. Example: supplemental curricular lessons and activities for secondary school students.

Effectiveness: The degree to which a problem associated with fluctuating water levels is resolved or made worse by implementation of a measure. (For consideration within the evaluation framework.)

Efficiency: A comparison of the benefits gained and the costs incurred in implementing a measure in response to a problem associated with fluctuating water levels. (For consideration within the evaluation framework.)

Electric Power Interest: Power interests are composed of all forms of electrical generation that depend on water as an integral part of power production process. The interest uses the Great Lakes and the St. Lawrence River for shore access service and water supply for hydro power head, cooling water and steam power and therefore includes hydro power, nuclear power, and fossil fuel-fired electric power.

Empirical: Relying or based solely on experiment and observation rather than theory.

Environment: The natural conditions and resources fundamental to sustaining life and the well-being of mankind and wildlife. In the context of this IJC study, these concerns relate to the ways in which fluctuating water levels affect such interests as domestic water supply and sanitation, agriculture, recreation and tourism, use of shore property, both public and private, flood control, and wildlife habitats.

Environmental Integrity: The sustenance of important biophysical processes which support plant and animal life and which must be allowed to continue without significant change. The objective is to assure the continued health of essential life support systems of nature, including air, water, and soil, by protecting the resilience, diversity, and purity of natural communities (ecosystems) within the environment.

Environmental Interests: This class of interest is primarily concerned with the environment in its own right and not with any specific use or exploitation from the Great Lakes Ecosystem. The class is represented primarily by naturalist and conservation groups and government agencies with a mandate of preserving the environment.

Equitability: The assessment of the fairness of a measure in its distribution of favorable or unfavorable impacts across the economic, environmental, social, and political interests that are affected.

Erosion: The wearing away of the shoreline and lake or riverbed by the action of waves and currents. Shoreline erosion on the Great Lakes is most often a result of the combined action of waves and currents.

Evaluation: The application of data, analytical procedures and judgment related to criteria to establish a judgment on the merit of a measure, policy or institution. Evaluation is a process which is conducted <u>both</u> within formal studies <u>and</u> by separate interests, although different data, procedures and criteria may be employed in the evaluation by different interests.

Evaluation Framework: A systematic accounting of the criteria considered and methodologies applied in determining the impact of measures on lake levels, components of the environment, stakeholders, and stakeholder interests.

Evapotranspiration: The loss of water from the soil by evaporation and transpiration (the passage of water from plants through membranes or pores).

Governance System: The complex of interest, policy and institutions which result in decisions on measures that are adopted over time.

Government Interests: These interest include all levels of government, local, regional, state/provincial and federal.

Groundwater: Subsurface water occupying the zone of saturation. In a strict sense, the term is applied only to water below the water table.

Group Depth Interviews (GDI's): A technique used in the field of marketing to gather perceptual data from a small group of representatives of local interests and governments on the following: the problems caused by different lake levels; the opportunities presented by different Measures; the factors involved in decision making about adopting Measures; and the consequences of Measures. It should be noted the GDI's reflect accurately the perceptions of the attendees but do not necessarily reflect the perceptions of all individuals within an interest.

Hanging Dam: A form of ice jam.

Hydrodynamics: A branch of science that deals with the motion of fluids and the forces acting on solid bodies immersed in fluids and in motion relative to them.

Hydrometeorology: A branch of science concerned with the study of the atmospheric and land phases of the hydrological cycle, with emphasis on the interrelationships involved.

Ice Boom: A structure installed to aid in the formation and maintenance of an ice arch at the head of a river, and thus reduce the adverse effects of ice on river levels and flows.

Ice Jam: An accumulation of river ice, in any form, which obstructs the normal river flow.

Ice Retardation: The difference between the amount of water discharged at given lake and river stages under open water conditions and under ice conditions.

Impact Matrix: A display which contains across-the-board assessments of how the various measures analyzed impact on the natural environment and all identified stakeholders and their interests, using the criteria agreed upon in the evaluation framework.

Implementation Cost: There are three costs that governments must assume when implementing any action; the initial or capital cost of implementation, costs associated with operation and maintenance of an action, and any compensatory costs.

Implementability: The ability to put into effect a measure considering factors of engineering, economic, environmental, social and institutional feasibility. (For consideration within the evaluation framework).

Implementability and Political Acceptability: The coalescence of sufficient support to endorse a measure and the identification of a legal or institutional mechanism able to be applied to put the measure into effect. The greater the breadth of support, agreement, and consensus among affected interests, the more likely is the measure to be politically acceptable and implementable. The more demonstrable the feasibility of a measure, in its engineering, economic, environmental, social, and financial aspects, the more likely it is to be politically acceptable and implementable.

Implementing Authority: Any governmental agency at any level having appropriate authority to authorize and execute the implementation of any particular action and the jurisdiction to enforce an action.

Infiltration: Movement of water through the soil surface and into the soil

Institution: An organization of governmental units which have the authority and ability to facilitate and/or make decisions affecting the implementation of measures.

Interests: Any identifiable group, including specialized mission agencies of governments which perceive that their constituents/ members welfare is influenced by lake level fluctuation or policies and measures to address lake level fluctuation, and are willing and able to enter the decision making process to protect the welfare of their constituents/members.

Interest Classification System: A categorization of the different types of impacts caused by fluctuating water levels. Envisioned as part of an Impacts Matrix whereby the affects of introducing various measures on each area of impact can be displayed.

Investment: Expenditure made by an interest in one time period to capture benefits in another period. The investment decision presumes knowledge and understanding of future risks and uncertainty.

Lake Outflow: The amount of water flowing out of a lake.

Lake Years: A hydrologic year considered to begin in August.

Location Benefit: Positive effect on the welfare of an interest derived from shore location and water level situation.

Location Cost: Negative effect on the welfare of an interest derived from shore location and water level situation.

Low Water Datum: The plane on each lake to which navigation chart depths and Federal navigation improvement depths are referred. Also referred to as Chart Datum.

Marsh: see "Wetlands".

Mass Transfer Relationship for Evaporation: An application of Dalton's Law, where evaporation is considered to be a function of the wind speed and the difference between the vapor pressure of saturated air at the water surface and the vapor pressure of the air above.

Measures: Any action, initiated by a level(s) of government to address the issue of lake level fluctuations, including the decision to do nothing. Measures are defined by three elements. The first element is the specific investment or action intended to affect the land and water resource and/or the human use of the land and water resource. The second element is the manner in which the socio-economic cost burden for an action is distributed (i.e. who pays?). And the third element refers to the implementing authority (i.e. who is responsible for executing and enforcing the action). Actions have been classified into six types:

<u>Type 1 - Regulation and Diversions</u>: Any engineering action which can alter Great Lakes water supplies, water levels and flows.

<u>Type 2 - Land and Water Adaptations</u>: Actions which involve government investment to adapt to or modify local land and water use in an effort to adapt to water level fluctuations and natural shore processes.

<u>Type 3 - Restrictions on Land and Water Use</u>: Actions whereby governments restrict how interests may use the land and water of the Great Lakes Basin.

<u>Type 4 - Programs to Influence Use</u>: Public programs and policies to provide information and alter financial incentives to influence the ways in which interests make decisions about the use of the land and water.

<u>Type 5 - Emergency Response</u>: Actions by governments to emergency situations. These are short-term measures to ease immediate problems.

<u>Type 6 - Combinations</u>: Two or more of the above types of actions combined to address the issue of fluctuating water levels.

Meteorological: Pertaining to the atmosphere or atmospheric phenomena; of weather or climate.

Negotiation: The process of seeking accommodation and agreement on measures and policies among two or more interests having initially conflicting positions by a "voluntary" or "non-legal" approach.

Net Basin Supply: Represents the supply of water a lake receives from its own basin less the losses by evaporation from the lake surface and loss or gain due to seepage, and the inflows to the lake and the outflows from it.

Physiography: A descriptive study of the earth's surface.

Policy: Policy may cause certain positions to be taken by the governments without evaluation, and may result in positions of other interests to be discarded or accepted without evaluation.

Position of Interests: The perceptions, beliefs and preferences of interests regarding fluctuating water levels, implications of those levels, and acceptability of a measure or policy to an interest. Positions are based upon an evaluation process. Positions may be directly stated or may be inferred by supporting or opposing activities taken by the interest in the decision making process.

Public Communications: Activities where the purpose, design, and plan intends for two-way communication for a defined period of time between Study personnel and the public or various publics. Examples: the Toledo Public Information Meeting and the Public Comment Process on the Task Force Report and Background Paper.

Public Information: Activities where the purpose, design, and plan intends to deliver information to the public or various publics. Examples: press releases and articles in the IJC's Focus Newsletter.

Public Involvement: Activities where the purpose, design, and plan is such that members of the public or various publics are engaged in the Study on a continuing basis with other "expert" resources. Example: a member of an interest group serving as a functional group member.

Public Participation: Activities where purpose, design, and plan intends that members of the public have an opportunity to participate for a defined period of time in a Study activity. Example: input into a portion of the work activities of a functional group through a workshop.

Recreational Interests: Non-riparian recreation interests include individuals, some of which are represented by specialized associations, which are located both inside and outside the Great Lakes Basin. This interest does not include those who own shoreline property. These interests seek access to the lakeshore and to some extent depends upon the habitat services of the lakes for serving its interests. Recreation interests benefit from angling, hunting, non-consumptive recreation, boating, swimming, and camping.

Regression Equation: A mathematical expression which statistically relates two or more variables.

Regulation: In accordance with a rule designed to accomplish certain goals. In this study, the term applies both to controls of water levels and controls of land and water use.

Riparian: The interest group is comprised of very many individuals, some of which are represented by various coalitions and associations with a wide range of organization and political strength.

Riparians: Persons residing on the banks of a body of water.

Robustness: The breadth or depth across fluctuation effects or across stakeholders of the effectiveness of a measure in resolving a problem associated with fluctuating water levels under a variety of changing conditions. (For consideration within the evaluation framework).

Runoff: The portion of precipitation on the land that ultimately reaches streams and lakes.

Seiche: A standing wave oscillation of a body of water that continues, pendulum fashion, after the cessation of the originating force.

Sensitivity: The degree to which an interest is effected by, receives benefits from, or suffers consequences of, water level fluctuations. Sensitivity is related to the preparedness of the interest to the effects of levels and the ability of the interest to adapt. (see also "Adverse Consequence - FG3 Operational Definition).

Snowpack Water: The depth of water which would result from the melting snow cover of a given area.

Social Desirability: The continued health and well-being of individuals and their organizations, businesses, and communities to be able to provide for the material, recreational, aesthetic, cultural, and other individual and collective needs that comprise a valued quality of life. The satisfaction of this objective includes a consideration of individual rights, community responsibilities and requirements, the distributional impacts of meeting these needs, and the determination of how these needs should be achieved (paid for) along with other competing requirements of society.

Socio-economic Conditions: Pertaining to the demographics of a region.

Stakeholder: An individual, group, or institution with an interest or concern, either economic, societal or environmental, that is affected by fluctuating water levels or by measures proposed to respond to fluctuating water levels within the Great Lakes-St. Lawrence River Basin.

Steady-state: No change over time.

Systems Approach: An analysis which is structured in such a way as to identify the many interrelated problems and interests affected by fluctuating water levels in the Great Lakes-St. Lawrence River Basin. This means an overriding concern that all aspects of the problems associated with fluctuating water levels be analyzed and evaluated, and their linkages be identified and weighted as to the degree of sensitivity in the system.

Transportation Interests: Transportation includes movement of goods in Great Lakes-St. Lawrence shipping channels and into and out of Great Lakes-St. Lawrence ports. Transportation interests are comprised of two major sub-classes: ocean going and lake carrier shipping companies, often represented by shipping associations, and ports, often represented by port associations. Associated with the lake transportation interests are other interests within the regional transportation infrastructure, including truck and rail interests.

Uncertainty and Risk: The evaluation of a proposed measure in terms of the unpredictability and magnitude of the consequence which may follow, the detectability of anticipated or unanticipated consequences, and the ability to reverse, adapt, or redirect the measure, depending on its effects.

Urbanization: The change of character of land from rural to urban.

Water Supply: Water reaching the Great Lakes as a direct result of precipitation, less evaporation from land and lake surfaces.

Watershed The area drained by a river or lake system.

Wetlands: "Lands where the water table is at, near or above the land surface long enough each year to support the growth of hydrophytes (plants which prefer wet conditions), as long as other environmental variables are favorable." (Cowardin, et.al., 1977) Along the Great Lakes shoreline they include marshes, swamps and other lands generally considered to be potential havens for fish and wildlife areas.

"What If" Modelling Capability: The ability to simultaneously determine the impacts of many different stakeholders and their interests in response to the implementation of a wide range of measures to deal with problems associated with fluctuating water levels in the Great Lakes-St. Lawrence River Basin.

APPENDIX D-2

THE GREAT LAKES: ECOSYSTEM PERSPECTIVE -- IMPLICATIONS FOR WATER LEVELS MANAGEMENT

I. THE CONTEXT - A WHOLE SYSTEM PERSPECTIVE

Functional Group 5

June 14, 1989

THE CONTEXT - A WHOLE-SYSTEM PERSPECTIVE

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I. THE CONTEXT - A WHOLE SYSTEM PERSPECTIVE

WHY A "SYSTEMS APPROACH"

1.1 Meaning of System

The term "system" is used in our language so widely, and liberally that it is easy to miss its underlying significance. In its loose daily usage the term denotes any assembly consisting of at least two distinguishable components, the totality of which is identified by virtue of some logical consistency. Thus we speak of a system of law, a production system, a communication system, a mechanical system, an ecological system, and the like. The concept has a deeper significance, however, which is rooted in fundamental issues concerning the scientific method and our view of the world. It has to do with the fundamental recognition of the essential complexity, irreducibility, and interconnectiveness, that characterizes system-entities.

Emphasis on these characteristics emerged in the early part of the 20th Century as science was reaching severe limitations in applying its classical, essentially reductionist, analytical method, which had been immensely successful in guiding human knowledge since the time of the early Greek philosophers.

The successful application of the classical reductionist model, and its analytical procedures, depends essentially on two basic conditions. First, parts of an entity studied must be independent to such a degree that they can be analyzed separately without affecting results pertaining to the whole. Interactions between parts, in other words, must essentially be negligible. Second, it must be possible to simply add up (linearly) descriptions of single parts in order to obtain a complete picture of the behavior of the whole.

That these conditions are not fulfilled by complex assemblies that are richly connected and that the world is made up, to a great extent, precisely of such internally richly connected dynamic organizations was an important revelation, which, beginning in biology, led to the development of a "synthetic" model of thought emphasizing the notion of whole systems and the interdependence of their parts. General System Theory thus emerged as a complementary model to the atomistic classical view of the world.

From the view point of System Theory, a number of systems characteristics-in-principle are invoked. They include the following:

- The notion of "whole-system:" The idea that there are aspects of the whole that are not captured by any of the parts alone.
- The notion of connectivity: Emphasizing a high level of interconnectiveness and the mutual effects of parts on each other and on the whole.
- The notions of complexity and irreducibility: Namely, that complexity is a genuine property and that complex systems cannot be handled effectively by reduction to simple parts.
- Finally, the notion of synergy: The emergence, through interactions, of novel properties that are not inherent to any specific single part, and the in-principle unpredictability of the whole from the behavior of the parts.

1.2 A Systems Approach and Its Implications for Action

System-entities thus require a particular approach if they are to be "handled" effectively. The issue which may appear too esoteric, or "theoretical," at first glance has important practical implications for management. For ultimately, if we approach a dynamic process as if it were a static object, a complex system as if it were a trivial assembly of independent parts or a simple clock-like mechanism, we are only likely to be frustrated by unexpected, often undesired, baffling results.

The point is this: How we manage social affairs and how effective are our actions is very much dependent on how effective, as guiding principles, are the models we have of the world. Using an erroneous road map is only likely to lead us astray and, in fact, the results of employing reductionist strategies in the management of complex systems are evident in mounting world-around problems encountered in the social, economic, environmental, and other domains.

In specific relation to the Great Lakes, measures aimed at alleviating adverse consequences of fluctuating water levels are applied in a complex systemic context characterized by high diversity, a high rate of interconnectiveness and inter dependence, high rates of change, and the need to integrate many conflicting forces. This context must be well understood for public policy to be effective and management to succeed. The development and adoption of a system, or ecosystem, perspective is, therefore, important.

The need for a comprehensive ecosystem approach was recognized in previous IJC documents and, in fact, the Great Lakes Water Quality Agreement of 1978 commits to a concept of ecosystem management defining the Great Lakes ecosystem as "the interacting components, of air, land, water and living organisms, including man, within the drainage basin of the St. Lawrence River...," thus acknowledging the interdependence and inseparability of the system's component parts.

As various observers have pointed out, however, this recognition remains, to date, mostly in rhetoric form and has not yet been translated into a coherent policy and effective management practice.

Moving from rhetoric to effective action will ultimately require at least the following:

- A re-orientation of thinking by all key players and a widespread adoption of the ecosystem perspective.
- The development of a comprehensive, coherent strategy for addressing the issue of fluctuating water levels and a consistent approach to its implementation and management.
- The emergence of the appropriate governance structure integrating the various jurisdictions involved, facilitating a consistent approach and allowing for constructive participation of all stakeholders.

The following sections represent an attempt to explore some significant systems characteristics and highlight their implications.

1.3 A Note on the Systems Diagrams

The systems diagrams that accompany the text are derived from a methodology known as System Dynamics. This methodology focuses on portraying the systemic characteristics of a given situation by identifying the key variables, the major components, of the systems under investigation and tracing the interactions between them.

The arrows that link key variables indicate important interactions and signify cause and effect relationships. They are thus used to map the underlying structure of a system's dynamic behavior. The crucial aspects of this underlying structure relate to the identification of circular cause and effect relationships, or feedback loops, and these give important, sometimes counterintuitive insights, into behaviors that can be expected of the system involved.

The feedback loops themselves belong generally to one of two types. The first type of loops, referred to as "positive" feedback loops act to cause the value of particular variables to amplify, sometimes at a geometric rate. A typical example can be found in the case of the dynamics of population growth where the more people are born the more the expansion of the population as a whole in a process, which unfolds at an ever increasing rate until the effect of a new factor halts or reverses the trend. The other type of loops, referred to as "negative" feedback loops, act to maintain the value of a particular variable around a given level. The general effect is examplified by the working of a thermostat that will start a furnace when temperatures drop below a prescribed level and will shut it off when that level is reestablished.

Note that the terms "positive" and "negative", as used in the case, do not carry the value connotation of "good" or "bad."

AN OVERVIEW OF THE SYSTEM

2.1 Introduction

The context for water levels related interventions comprises a complex biophysical system which, in addition to climatic and hydrological factors, involves ecological, social, economic, and political dimensions as well.

Many factors are involved which together take part in an enormously complex web of interactions forming important feed-back relationships. These form underlying structural patterns, which work to amplify or resist changes in the system. It is, therefore, not always easy to foresee overall effects of specific interventions and an understanding of the system as a whole as well as its internal dynamics is critically important. This complexity is not an argument against trying to solve problems created by fluctuations. However, the complexity requires that solutions be carefully crafted, keeping the many different interacting factors in mind. This means, further, that solutions cannot simply focus on one aspect or cause, but must be multi-faceted and comprehensive in nature.

From a practical viewpoint, problems concerning basin wide management, including such issues as water quality and pollution, shoreline development, navigation, water diversion (within or outside of the basin), and effects of water level fluctuations, are not simple isolated problems. They interact and affect each other in a number of important ways.

2.2 Key Elements of the System and Their Interaction

From the view point of issues concerning fluctuating water levels, a number of factors emerge as important components. These include hydro-climatic factors affecting fluctuations, the basin's "natural" ecology, human activities as characterized by various socio-economic interests, the existing system of governance, and the measures applied to affect fluctuating water levels. These factors, or key components of the system, are each an exceedingly complex system in their own right and because of the web of their interactions, potential interventions are likely to produce direct, as well as indirect, impacts of various kinds. From a management view point, perhaps the most important statement that can be made as we face the challenge of this complexity, is that neither the system as a whole, nor its major component parts, are subject to complete human control.

Figure 1 illustrates the pattern of cause and effect relationships that exist between key components of the system, highlighting the interdependent way in which they interact. For example, various climatic and hydrological factors affect water fluctuations, which in turn impact on human activities. But in addition to the obvious loop of affecting fluctuations through measures, the density of human activity, through its effects on the biosphere, e.g., the "greenhouse effect," may cause changes in levels by affecting long term climatic trends. The point is that the two loops operate on different time scales and their interaction may exasperate unintended adverse effects. An example is, if implementation of measures to reduce water levels coincide with climatic impacts that in the long term are likely to cause water level to fall.

Human activities, as related to the various socio-economic interests in the Great Lakes Basin, constitute a key element in the system. These are an integral part of the ecology of the basin, and although they represent only one component in the system overall, this effect is exerting a tremendous pressure on the "healthy" balance of the whole. Policies for applying measures and for their management should, therefore, be directed not only at the physical parts of the system but at the human component as well. Governance as a special class of human activities that concerns the planning, implementation and management of measure is, therefore, of primary importance and, accordingly, it is isolated from the more general concept of "human activities".

Henceforth, in characterizing the system as a whole, the discussion will focus on the following four major components:

- The climate and hydrology-related factors that effect water levels.
- The basin's "natural" ecology.
- Human activities as related to the various socio-economic interests.
- Governance processes, in particular as they pertain to the question of measures.

An overview that integrates these components in a slightly higher level of resolution is depicted in Figure 2. It can be summarized as follows: Flows of water through the basin and fluctuating lake levels are predominantly affected by natural factors such as precipitation, but are subject to human

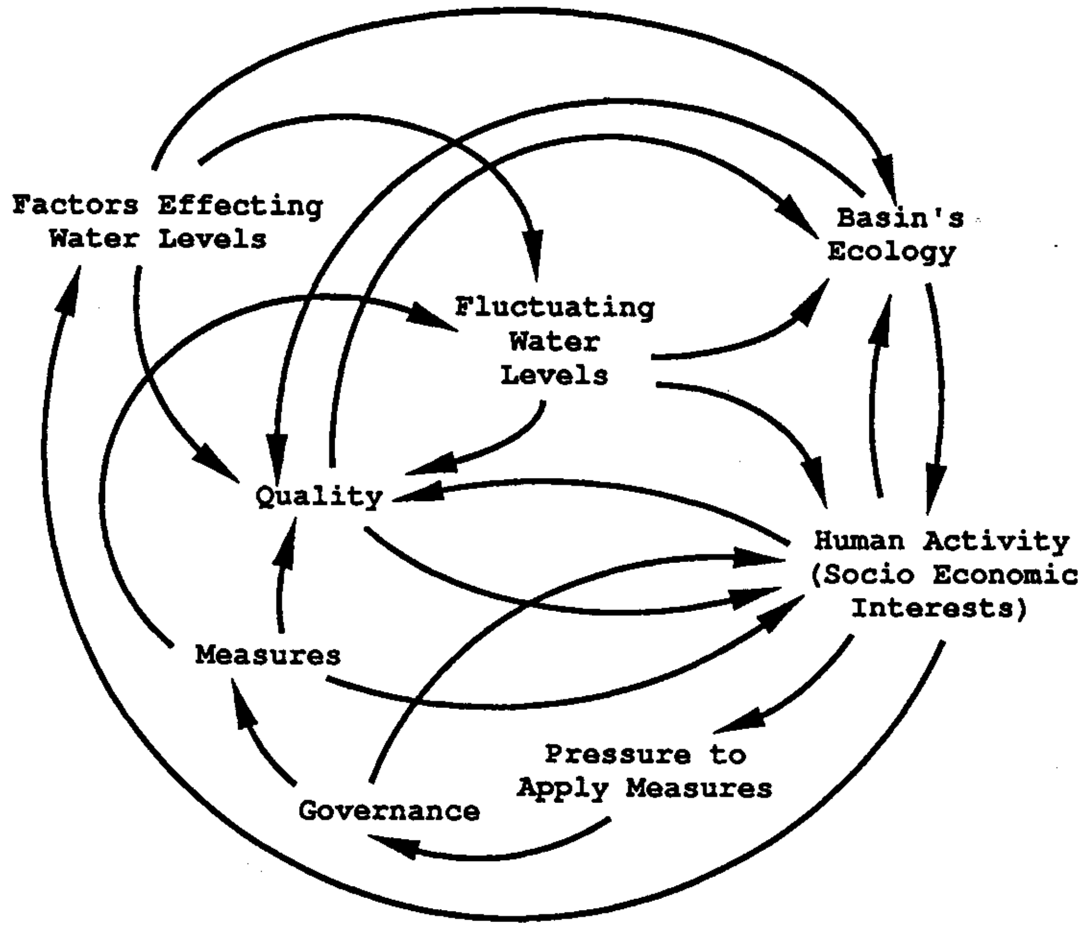

Figure 1: A system's overview depicting interacting primary components including governance as a key element related to human activities.

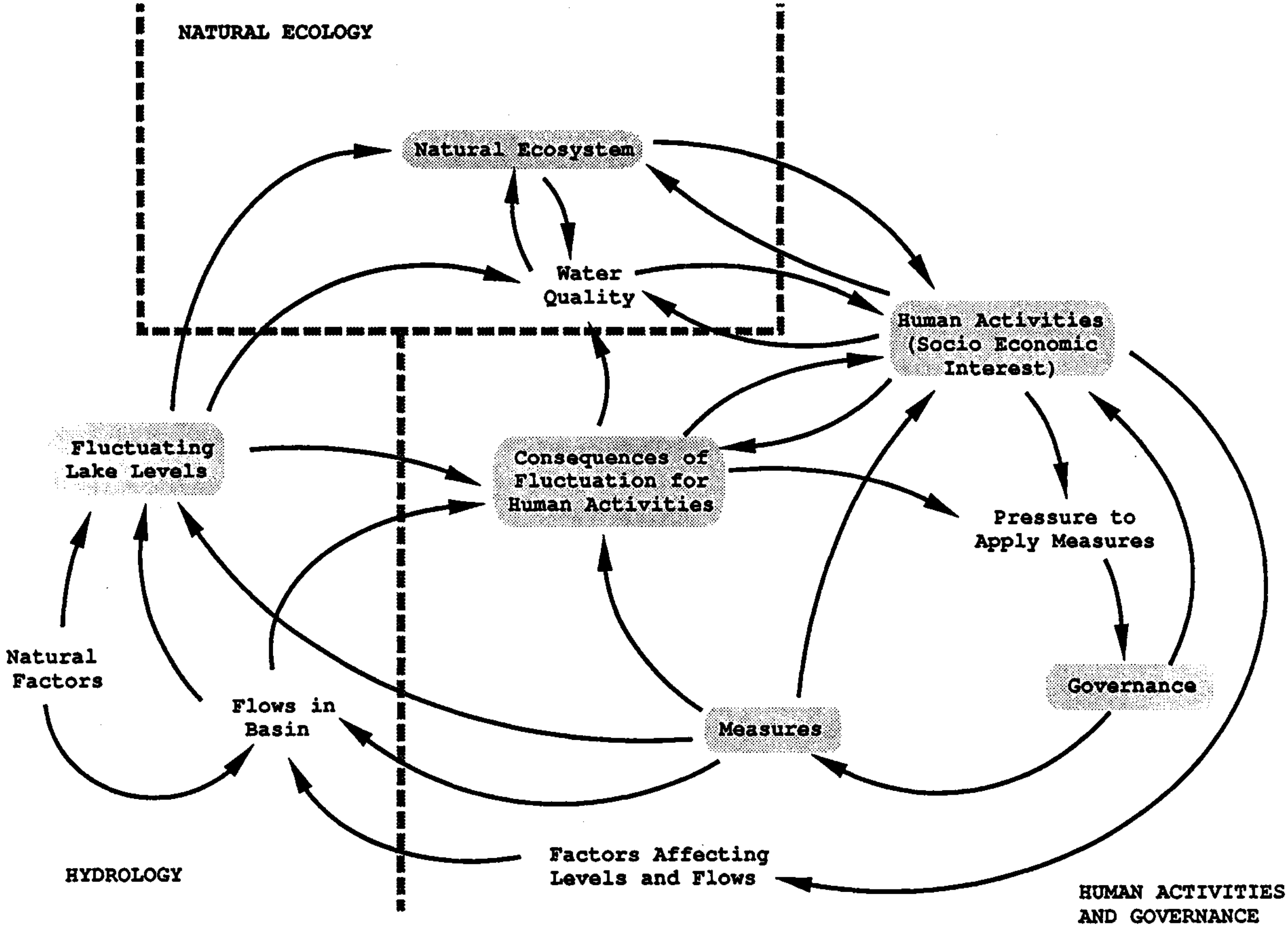

Figure 2: System overview indicating focus on the interaction of hydrology, natural ecology, human activity and governance.

influences as well. Some of these influences are byproducts of activities such as the consumptive use of water, generation of hydroelectric power, and development of the lakeshore (which affects runoff) while others relate to measures deliberately designed to modify fluctuations, and control water levels and flows. Natural factors that contribute to fluctuations vary on a number of different time scales ranging from climatic changes that occur over long periods of time (although man's influence through the "greenhouse effect" may be accelerating some of these) to storms that develop within hours.

Fluctuating water levels have, in turn, consequences that impact on human activities. Some of the consequences, such as storm damage, are dramatic and readily command the public's attention. Others, such as ships having to reduce their loads due to low levels, are more subtle, but may be equally significant to those who depend on the lakes for transportation. Some consequences arise from fluctuating flows rather than levels and can become significant, especially in times of drier climate. Low flows in tributaries due to a drier climate, for example, may be inadequate to dilute sewage or accept thermal discharges from power plants. In addition to fluctuating water levels, fluctuations in flows and their consequences are important to study as well.

The nature of human activities, also affect, in themselves, the vulnerability of various users of the lakes to fluctuations. Building structures close to the water or using ships with deep drafts (that cannot navigate channels when levels are low) affect vulnerability and contribute to consequences of fluctuations as surely as do the fluctuations themselves. Managing human activities to reduce vulnerability ought to be, therefore, an essential part of any strategy to reduce the consequences of fluctuations.

Human activities and the hydrology of the basin interact with other elements of the natural ecosystem. Fluctuating levels, for example, are vital for keeping coastal wetlands healthy. Human activities can preserve the integrity of wetlands or can damage them. Wetlands, like other components of the ecosystem, also serve as a buffer, offering protection for human activities against fluctuations, and, when not overwhelmed by human impacts, play an important role in processing toxic contamination and excess nutrients, thereby helping to maintain water quality. Wetlands and other parts of the natural ecosystems are affected by the density and nature of human activities, but they also affect human activities, in turn, by providing valuable esthetic experiences, many important opportunities for enjoyment, economic benefits such as those derived from recreational fishing, and, in general, by ultimately having an impact on overall well being and the quality of life.

As the set of relationships in Figure 2 suggest, the "boundary" of the system studied should include the flows in the tributaries and in the St. Lawrence basin, as well as the levels of the lakes themselves. In addition to questions of quality, it should also include factors affecting and affected by water quality. Though not the focus of the current reference, water quality may interact in a number of critical ways with quantity, especially at times when flows in tributaries and levels in their estuaries are low. Low levels and flows may reduce water available for consumptive uses for example, and poor water quality may exacerbate this consequence of fluctuations especially in particular sub-basins. At the same time, low flows can also worsen quality. As mentioned earlier, reduced flows in tributaries can decrease capacity to dilute sewage and industrial contaminants and to absorb thermal discharges from power plants. These relationships between quality and quantity are important and will be discussed further in a later section on the natural ecology.

2.3 Understanding the System as a Guide to Action

In principle, two systemic aspects are enormously important for the development of effective policies for basin-wide management. As mentioned earlier, the first has to do with a comprehensive whole-system perspective. Only the recognition and understanding of the complex variety of interacting variables and the ways they affect one another can yield a sound basis for guiding interventions. The second aspect has to do with specific ways in which particular components of the system interact: The nature of their dynamics, underlying structure, and effect over time. This is important since, in some cases, the underlying dynamics of the forces involved may produce results which are contrary to intended interventions.

A typical example of such a case is illustrated in the interaction of damage, implementation of protective structures, and shoreline development as depicted in Figure 3. As shown in the diagram, adverse effects of fluctuating water levels may bring about a demand for implementing protective structures. When these are put in place, they may alleviate some of the adverse effects. At the same time, however, they may cause a sense of security that will increase the intensity of shoreline development thus increasing vulnerability and potentially amplifying future adverse effects.

There are a number of circular loops, such as those shown in Figure 3, operating throughout the system. As a guide to effective action they are important to identify and understand,

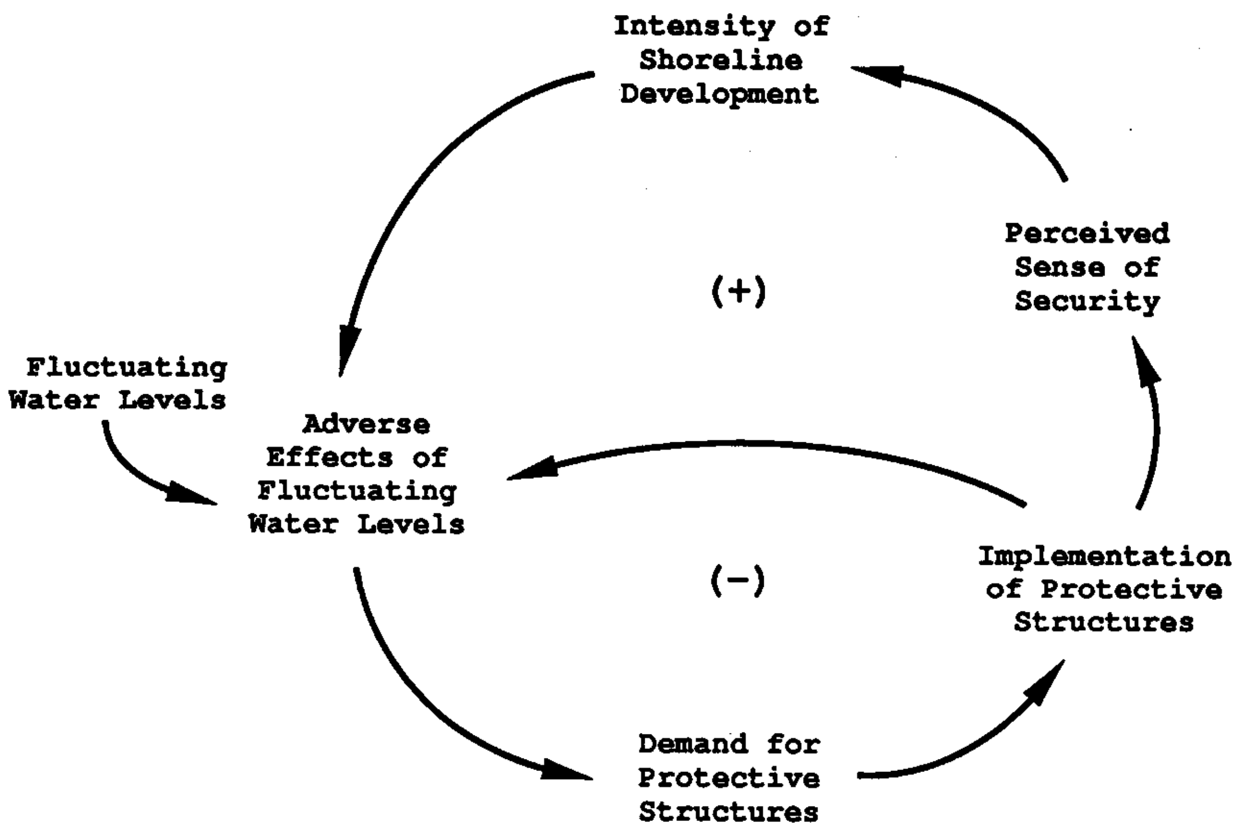

Figure 3: Fluctuating water levels, protective measures and shoreline development showing feedback loop which can cause unintended adverse effects when a sense of security brought about by implementing measures accelerates development and increases future potential vulnerability

since the particular way in which these loops interact over time drives the actual behavior of the system, some aspects of which may be especially significant; in this case, unintended consequences of protective structures. The example cited above does not suggest that protective structures be avoided in all cases, but rather that, when they are built, they should be accompanied by other measures, such as land use controls, designed to keep adverse consequences from escalating and offsetting the benefits intended of the structures above.

2.4 Resolving the System's Overview into its Key Components

In the following sections the system's overview will be resolved into its four major components and these will be developed in further details. In each case selected subcomponents will be described, various aspects of their underlying structures and the related behaviors analyzed, and implications will be highlighted that are relevant to the development of an overall policy. Throughout, several key items will be emphasized:

- Implications of changes in one part of the system that at first glance may be seemingly unrelated to others.
- The potential for unintended consequences of otherwise apparently reasonable interventions as they relate to the operations of particular underlying feedback loops.
- The need for a balanced, multifaceted approach that is the direct result of the system's complexity and the various dimensions of its various interacting components.

THE HYDROLOGY OF THE BASIN, CAUSES OF FLUCTUATIONS, AND IMPLICATIONS FOR MEASURES

3.1 Causes and Consequences of Fluctuations - An Overview

Figure 4 focuses on four key aspects of the hydrology of the Great Lakes Basin relating to fluctuations in absolute lake levels and their consequences. These are:

- o Static levels that are affected over time primarily by precipitation, moderated by such processes as runoff and groundwater flows. Both low and high static levels can have important consequences for human activities.

- o Storm effects that can raise absolute levels significantly above static levels for brief periods of time and are responsible for the more serious damage caused by fluctuations.

- o Human activities that affect levels and fluctuations both as a by-product of non directly level-related activities, and through deliberate control measures.

- o Consequences of fluctuations, including costs related to storm damage flooding, and costs related to adverse consequences of low water levels.

The key question examined as these phenomena are presented in greater detail is the extent to which measures can reduce variability in levels and the consequences that result.

3.2 Determinants of Static Levels

The Great Lakes are a complex hydrologic system, consisting of a series of large lakes that are joined by connecting channels and which drain to the ocean by the St. Lawrence River. Natural sources of water to the system include direct precipitation, runoff from the land surface that drains into the lakes, and groundwater inflows. Water is lost naturally from the system by evaporation from the lakes, by groundwater outflows, and by flows into the St. Lawrence River. In addition, there are man-made diversions of water into and out of the system. Certain aspects of the system's hydrology make fluctuations inevitable and create limits to what can be done to control them.

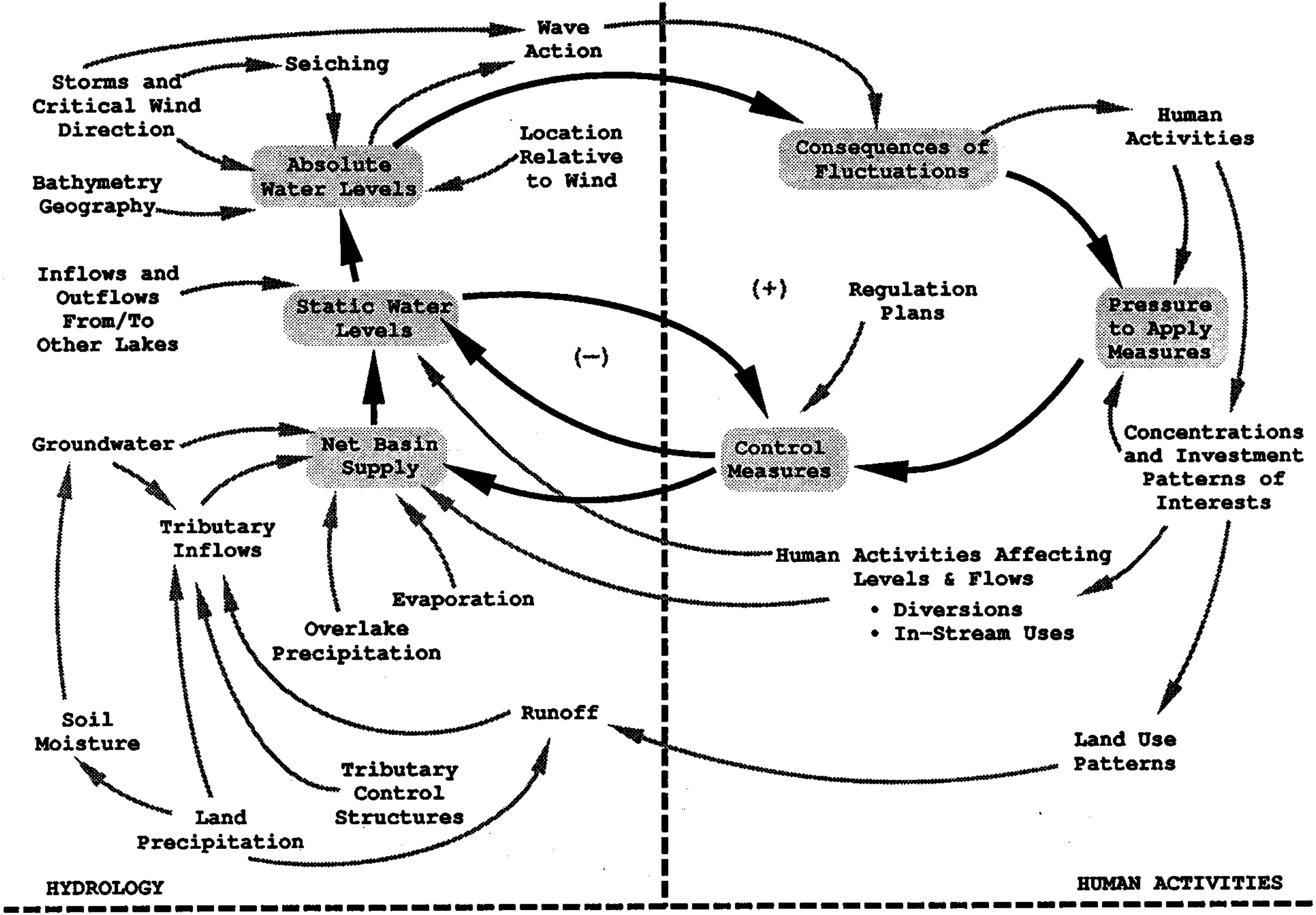

Figure 4: The key interaction between human activities and the hydrology of the lake is through consequences of fluctuations leading to pressure to apply control measures and possibly to measures being implemented.

3.3 Fluctuations in Static Levels

3.3.1 Role of Storage

The most extraordinary characteristic of the Great Lakes as a hydrological system and as a human resource is the tremendous amount of fresh water which they store. In addressing the issue of fluctuating lake levels it is essential to understand the role of the Great Lakes as a gigantic storage system. Human activity requires a continuous source of fresh water. Yet, precipitation, our only renewable source of fresh water, is an intermittent process and hence an extremely variable source of water. In order to overcome this variability, we rely on systems that store fresh water, such as natural lakes, reservoirs, or groundwater. The larger the volume of a given system relative to the supply of water, the greater the potential for reducing the variability in the water supply.

The Great Lakes have an enormous capacity to store water and, as a whole, constitute the world's largest surface body of fresh water. The total volume of fresh water in the lakes is over 50 times the average net supply to the basin. As a result, non-consuming users of Great Lakes water have a virtually infinite water supply that is always available, regardless of the weather. Current consuming users also have an unfailing source of water, although the total amount that can be consumed is ultimately limited by the average net supply and by the water needs of downstream users. (It should be noted that the average net supply to the Great Lakes is not extraordinary; in fact, it is not very different from the supply to other drainage systems in the region.)

The immense storage capacity of the Great Lakes has another implication of great practical importance -- it greatly dampens the variability of flows in the connecting channels and in the St. Lawrence River. The beneficiaries of this reduced variability are hydropower, shipping, and riparians. Few other hydropower plants in the world have as reliable a source of water as do those located on the Great Lakes. Users of the lower lakes in the system also benefit from storage in upstream lakes, since this storage reduces the variability of the flows received from these lakes.

As shown in Figure 4, these flows combine to affect static water levels on the lakes. Each lake is affected by flows from upstream and flows to downstream lakes as well. Static levels vary with seasonal fluctuations in precipitation. There are also multi-year cycles of precipitation that produce unusually large or small amounts in certain years. Finally, there are longer-term climatic trends that affect precipitation, such as those related to shifts in climate patterns, as well as the ones that may result from the often-discussed greenhouse effect.

Storm effects include higher absolute levels created by storms and seiches (an effect of low atmospheric pressure) and wave action. Storm effects vary based on local geography (e.g., bay vs. open lake), as well as characteristics of the storms themselves.

Human impacts, such as removal of water for consumptive use and changes in flows due to hydroelectric dams, navigational locks, and other instream uses also have an effect on static levels. Though some of these human impacts are currently relatively small (consumptive uses are less than 5% of total flow), they could grow over time, for example, if a drier climate required more use of water for irrigation. Consumptive uses could also have a more significant impact in certain sub-basins if they represent large fractions of the flows of particular tributaries. These uses could be quite vulnerable if the flows in such tributaries are reduced by persistently low rainfall. Development in the basin may have a marginal effect on levels by changing the rate of runoff into the lakes.

The other major human impact on static levels are control plans that modify lake levels to protect human activities around the lakes. These plans use structures already in place on connecting channels between the lakes, although a number of proposals for additional structures have also been made. The plans are administered by International Lake Level Regulation Board, and there are various options for mitigating adverse consequences of fluctuating water levels.

In the discussion below we review some critical aspects of the Great Lakes as a hydrological system and draw inferences that relate to the issue of mitigating damage resulting from fluctuating water levels, particularly those caused by high levels.

3.3.2 Hydrological Lake Level Fluctuations - The Corollary to Storage

A direct consequence of the role of the Great Lakes in averaging out the variability of basin supplies is fluctuating lake levels. In fact, fluctuating lake levels are the mechanism by which the lakes average out the variability of basin supplies. These hydrological fluctuations in lake levels occur at a variety of time scales, in accord with the scales of variation of basin supplies.

At time scales of a week or less, individual rainfall events can cause fluctuations in lake levels, although these are usually minor. At an annual time scale, all of the Great Lakes respond to seasonal fluctuations in rainfall, lake evaporation, runoff, and groundwater flow, the components of net basin supply. Further, all the lakes but Superior respond to seasonal fluctuations in the inflow from the next upstream lake, although it takes several years for changes in the outflow from Lake Superior to fully impact Lake Ontario. The range of normal seasonal fluctuations in the Great Lakes varies from about one foot on Michigan and Huron to about three feet on Ontario.

At time scales ranging from months to years, the lakes fluctuate in response to climatic anomalies in basin supplies. For example, the high water levels of 1985-6 were due to basin supplies which were 53 percent above the 1900-1985 mean. For the period from 1860 to 1988, the maximum range in annual lake levels varies from about four feet on Superior to about six feet on Ontario. Note that for individual lakes the maximum recorded range is only about two to three times the range of normal seasonal fluctuations.

3.3.3 Predictability of Lake Levels

Because of the immense storage capacity of the Great Lakes, it is possible to make reasonably accurate predictions of average lake levels for time periods of up to several months or more. Of course, the accuracy of these predictions decreases as the length of the time period increases. In general, for a given time period the accuracy is greatest for the downstream lakes, which have the smallest ratio of basin supplies to inflow from the upstream lake. Given the current state-of-the art of long-term weather forecasting, it is not yet possible to make reliable predictions of lake levels for periods much over six months.

It is possible to make reasonably accurate predictions of the magnitude of set-up and waves for individual storm events, though the predictions must be tailored for individual locations.

3.3.4 Statistical Characterization of Lake Levels

Even though it is not presently possible to predict reliably lake levels beyond six months or so, it is possible to estimate the probability that at a specific time in the future the level of a particular lake will exceed any given high level. Such estimates account for hydrologic factors controlling lake levels, as well as storm effects. It is also possible to estimate jointly the probability that waves with a significant wave height equalling or exceeding a specified value will be superimposed on a given water level.

This kind of probability information is extremely useful for optimizing the design of facilities that are potentially vulnerable to flooding and wave damage. It is also possible to estimate the probability that at a specific time in the future the level of a particular lake will persist below any given low level for any given duration. Such probabilities would be extremely useful in designing facilities which are subject to damage or failure in low water, such as water supply intakes.

Due to climatic uncertainties, the potential errors in both low and high water probabilities increase with the time interval of the prediction. However, well-conceived design strategies can account for this uncertainty.

It is important to note that at this time state-of-the-art probability estimates for either high or low water are not yet available and hence, decisions regarding shoreline activities have not been made in the best possible manner. Finally, it is possible to develop stochastic models of net basin supplies that can be used to generate independent, equally probable sets of time series of net basin supplies for the Great Lakes system. These time series, coupled with probability models of storm effects, can be used to evaluate the effects of various regulation strategies on water levels and flows.

3.3.5 Implications of Global Climate Change

There is limited evidence that in prehistoric times water levels in the Great Lakes were much more variable than they have been during the historic record, although it is extremely difficult to determine how much of this increased variability was due to variations in net basin supplies and how much was due to variations in the system hydraulics. With further research we may be able to make rough estimates of the prehistoric variability of net basin supplies. Once this has been done it will be possible to incorporate this information into stochastic models of net basin supplies, which, in turn, can be used to site shoreline structures or evaluate the potential of new control strategies.

There is also a growing consensus among climatologists that a continued rise in the atmospheric concentration of carbon dioxide will eventually alter our global climate as a result of the greenhouse effect. At this time the effects of such climate change on the Great Lakes are not yet known, although many researchers believe that the effect will be a decrease in net basin supplies. The massive quantity of fresh water stored in the Great Lakes system will guarantee those within the basin with access to the lakes a reliable source of water for many years, providing adequate time for them to adjust to the new level of net basin supplies.

If there were similar decreases in water supplies on large portions of the rest of the continent, there would be pressure to tap into this fresh-water source. This pressure would be especially difficult to contain if large federally subsidized diversions or control structure had already been built. Undoubtedly the lower water levels that would accompany a decrease in net basin supplies would create considerable hardships for many, if not all, Great Lakes users. In adjusting to lower water levels there would be an opportunity to avoid the mistakes of the past with regard to the siting of structures, however.

3.4 Storm Effects

Superimposed on the hydrologic fluctuations of lake levels are short-term fluctuations due to storm effects. The most important storm effects are waves and storm tides, which are caused by high winds, and storm surges, which are caused by the combined effects of high winds and strong atmospheric pressure gradients. The magnitude of the resulting fluctuations in lake levels depends on factors such as wind direction, duration, and velocity, as well as on local bathymetry, and are thus site specific. Lake level fluctuations due to storm effects normally persist for less than a day. The temporary increase in lake level resulting from a storm tide or a storm surge is termed set-up. The maximum observed set-up on the Great Lakes varies from about two feet on Ontario to about fourteen feet on Erie.

Waves are rapid fluctuations of the water surface both above and below the static water level. During a storm event successive waves vary in height. Wave heights are usually characterized by the significant wave height, defined as the average height of the highest one-third of the waves in a given storm. The estimated 100-year significant wave height varies widely throughout the Great Lakes, attaining a maximum of about thirty feet on Lake Superior. Note that the significant wave height must be divided by two to determine the height of the wave above the static water level.

Table 1 illustrates the relative importance of long-term hydrologic and short-term storm-related factors affecting high lake levels for Lakes Superior, Huron, Erie and Ontario. (Lake Michigan is not included because the estimates of the values of columns 2 and 4 are not available). The first data column gives the average long-term water level for each lake. The second column gives the estimated 100-year maximum average monthly lake level. On average, in one year in a hundred the maximum average monthly water level will equal or exceed that value. Because it is based on average monthly levels, it is indicative of long-term hydrologic variability, rather than short-term storm-induced variability. It does include, however, the effects of seasonality.

The third column gives the difference between the second and first column, and represents the 100-year increment in water levels due to long-term hydrologic variability. The fourth column gives the range in estimated 100-year storm set-up values for selected location on the lakes. A particular value represents the estimated storm set-up which will be equaled or exceeded at a given site on the average of once every 100 years.

By comparing columns 3 and 4 it can be seen that for all of the lakes shown, the 100-year increases due to long-term hydrologic variability (and seasonal effects) are of roughly the same magnitude as those due to short-term storm set-up. Column 5 gives ranges of one-half of the 100-year significant height. Note that for the lakes shown, the lake level increase associated with the 100-year significant wave always far exceeds that due to long-term hydrologic effects.

TABLE 1. 100-Year Water Levels on the Great Lakes (all values in feet)

Lake	(1) Long-Term Mean	(2) 100-Year Annual Max. Mon. Mean	(3) Difference (2)minus(1)	(4) 100-Year Storm Set-up	(5) 100-Year Wave
Superior	600.5	602.0	1.5	1.4-2.8	6 - 13
Huron	578.2	581.5	3.3	0.8-3.3	8 - 13
Erie	570.3	573.6	3.3	1.5-8.4	7 - 11
Ontario	244.0	247.6	3.6	0.8-3.5	8 - 14

Columns 2 and 4 are taken from Great Lakes Hazard Lands Technical Committee Report, Ontario Ministry of Natural Resources, 1988.

Column 5 is taken from Resio, D.T., 1976, Towards Design Wave Information for the Great Lakes, Report to: Great Lakes, Hydraulics Laboratory, U.S. Army Corps of Engineers, Vicksburg, MS.

3.5 Anticipating and Reducing Damage Due To Fluctuations: Need for a Balanced Approach

3.5.1 Quantifying Damages Due To Fluctuations in Flows and Levels

Fluctuations in water levels and flows in the Great Lakes system can cause severe damage to the many interests that utilize the system. In order to evaluate accurately the benefits of potential measures for reducing the damaging effects of fluctuating levels and flows, it is essential that we be able to quantify these damages. For some classes of interests, such as hydro ower and shipping, quantification of damages is relatively straightforward and has been accomplished to a reasonable degree of accuracy. This is not the case with riparians, particularly with respect to the damage associated with high water. It is our belief that there does not currently exist an acceptable quantification of the relationship between damage and water levels. This is due to lack of both data and consensus on the basic physical processes.

Damage to shoreline property results from erosion of the shoreline and from direct flooding, typically in conjunction with the destructive action of waves. The susceptibility of the shoreline to erosion varies widely throughout the system, depending mainly on the local geology.

Rates of erosion are reasonably well estimated throughout the Great Lakes system. However, the dependence of these rates on water levels is not known, although there is a growing consensus that erosion rates are much less dependent on water levels than once thought. Hence it is not possible to make reliable estimates for each lake of the dependence of erosion damage on water levels.

Flood damage presents a similar problem. Storm effects vary widely in the lakes. While there is readily available information on the statistical distribution of offshore waves, the estimation of the statistical distribution of waves at any particular onshore site requires extensive site-specific calculations. For a structure of known elevation at a given location, the estimation of damage for a given water level and wave climate is very tenuous proposition. Further, there does not exist for the various lakes, an accurate up-to-date catalog of existing structures and their relevant characteristics, including elevation and value. For all of the above reasons it is not now possible to make reasonably accurate estimates for each lake of the dependence of flood damage on water levels.

Such a capability is essential for the effective evaluation of proposed measures.

3.5.2 Measures for Reducing Damages Resulting from Fluctuating Lake Levels

There are a variety of measures that are available for reducing the damage associated with fluctuating lake levels. We will focus on the most important classes of these measures. Although they are described under three different headings they would ultimately offer the best opportunities when used in mutually reinforcing combinations.

- Control of Lake Levels

  Currently there exist two principal mechanisms that can be used to control long-term variations in lake levels and flows: Diversions and control structures. (It is not possible to control water level fluctuations resulting from storm effects.) Existing diversions were never intended as control mechanisms and, given current physical limitations, have relatively little potential for control. Control structures on Lake Superior and below Lake Ontario were designed and are operated to regulate flows from the respective lakes. Of these, the control works below Lake Ontario have a greater impact on water levels, reducing the maximum levels of Lake Ontario by about one foot and increasing the minimum lake levels by just under one half foot. (Even though the observed reduction in the maximum water level is significant, there is some evidence that the economic benefits of this reduction have been reduced by the encroachment of structures on the Ontario shoreline.)

  The extent of control of the Great Lakes can be increased by expanding the capacity of current diversion structures and by constructing new control structures on the presently uncontrolled lakes. The flow system that receives the Chicago diversion from Lake Michigan can safely handle up to about ten thousand cubic feet per second. If this system were modified to handle three or more times this amount, it could be used to ameliorate used to ameliorate high water levels on all of the Great Lakes, and could be particularly effective as a safety-valve for extreme high water levels. Such use could exacerbate low water levels, however, as the diverted water would be lost from the system. Further, use of any diversion to ameliorate high water levels could enhance the likelihood of water being diverted to meet a critical water need out of the basin and is, in any event, likely to meet with strong opposition.

  It is technically feasible to construct control works on the currently uncontrolled lakes, specifically the Michigan-Huron system and Lake Erie. The effectiveness of such control works would be severely limited by the fact that reducing the variability of water levels on the Michigan-Huron system and on Lake Erie will increase variability of flows into Lake Ontario. This results because the artificial reduction of the variability of water levels in a lake negates the natural ability of the lake to stabilize flows. In a system of similar lakes in series, the downstream-most lake offers the greatest potential for regulation of water levels (although there may be constraints on the allowable increase in variability of the flows in the channel draining the lake). The control of any additional lake is less effective from a basin-wide perspective, since its control increases the variability of its discharge and stresses the lakes below. Hence, if the lakes upstream of Ontario were to be controlled to the maximum extent possible, the benefits to the upstream riparians would be negated to a large extent by increased damages to Ontario riparians. These increased damages would result because of the loss of effective storage in the upstream lakes. Since such a result would not be equitable (and probably not cost-effective), new structures on the presently uncontrolled lakes would have to be operated in ways that would not increase damages in Lake Ontario. This constraint severely limits the effectiveness of any new control structures.

Further, the ability to control all of the lakes would create tremendous political stress, since it would require a coordinated regulation plan which would allocate the disbenefits of high and low water levels. During periods of extreme water levels there would likely be constant pressure to deviate from or modify the regulation plan. Not only would there potentially be conflict between traditionally opposing groups, such as riparians and hydropower interests, but new conflicts could develop, such as between riparians on different lakes. Even if there existed good information about the relative economic impacts of high water on riparians in the various lakes, it would be very difficult to resolve this conflict. However, as was previously noted, such information does not exist.

- <u>Local Protection of Shoreline Property</u>

An alternative approach to mitigating the effects of high lake levels is to protect locally shoreline property. Temporary protective strategies, such as emergency sandbagging, can be used in conjunction with short-term forecasts of storm effects. Long-term lake level forecasts can be valuable for triggering responses to high and low lake levels that require longer lead times, such as dredging or construction of dikes. The design of permanent protective works, such as breakwaters, would benefit greatly from site-specific information on probabilities of lake-level extremes resulting from both long-term and storm effects. The impacts of shore-protection works on adjacent shoreline needs to be carefully evaluated before such works are constructed. Shore protection structures can have adverse effects if not properly designed and are also subject to damage in severe storms. On the other hand, shore protection can often be used selectively in limited areas to deal effectively with fluctuations without having to affect levels of entire lakes.

- o <u>Rational Siting of New Shoreline Structures, Design Considerations, and other "Adaptive" Measures</u>

Well-developed strategies exist for risk-based design of shoreline facilities. These strategies account for the probability distribution of lake levels, the uncertainties in the probability estimates, the damages associated with various lake-level extremes, and the design life of the facility. Tax policy, land use regulations, and similar approaches belong to this category. These are all measures that rely on an adaptive approach to the inherent dynamics of the lakes themselves.

To date such strategies have not been widely used in the Great Lakes. The fact that these types of measures often conflict with the economic well-being of various interests may place some limits on their use as well. The limits to use of particular measures suggest that well-balanced combinations of measures are necessary for effectively dealing with fluctuations and their consequences.

3.6 Control in a Broader Context

It is appealing to look at the control of fluctuations as a hydrological process alone. However, because control interacts with a wide range of human activities that are affected by the lakes, it must be viewed in a broader context. Figure 5 highlights the key relationships that affect the control process. The process has two feedback loops at its core. One uses existing control measures to affect levels and bring them in line with targets. In the other loop, pressure for control measures resulting from consequences of fluctuations may lead to new measures and the use of existing ones to affect levels and thereby reduce consequences in the future. This pressure for control measures is very much a part of the control process as it affects what control measures are implemented.

Pressure for control measures, however, is affected by other factors in addition to the consequences of fluctuations. Specifically, there are two loops that can cause pressure for control to grow over time. One can cause pressure to grow as more control measures are implemented and there is greater potential for control. In the other, human activities on the lakes produce greater concentrations of interests and investments that, in turn, produce more dependence on the lakes and the need for greater predictability of the levels.

Increased pressure for control can have several possible outcomes:

- o Increasing dependency on control as interests come to expect that problems with fluctuations can be eliminated by control measures.

- o Greater rather than less fluctuation if control measures become extensive and are used vigorously in response to pressures for control. Responding too vigorously to pressure can produce "overshoot" that must itself be corrected by further use of controls. This kind of overshoot is unlikely at present, given the limited set of control measures available.

- o Increasing conflict about the use of control measures. Conflict arises because the interests using the lakes have very different needs. As the degree of control possible increases, conflict can intensify. Ironically, conflict about control measures can have a stabilizing effect (represented as a negative feedback loop in Figure 5) that works against excessive use of control measures. When viewed in this broader context that includes human activities, the need for judicious use of control measures within comprehensive sets of measures becomes even clearer. Control measures have a distinct role to play, but cannot be relied on as a sole or dominant approach to the consequences of fluctuations.

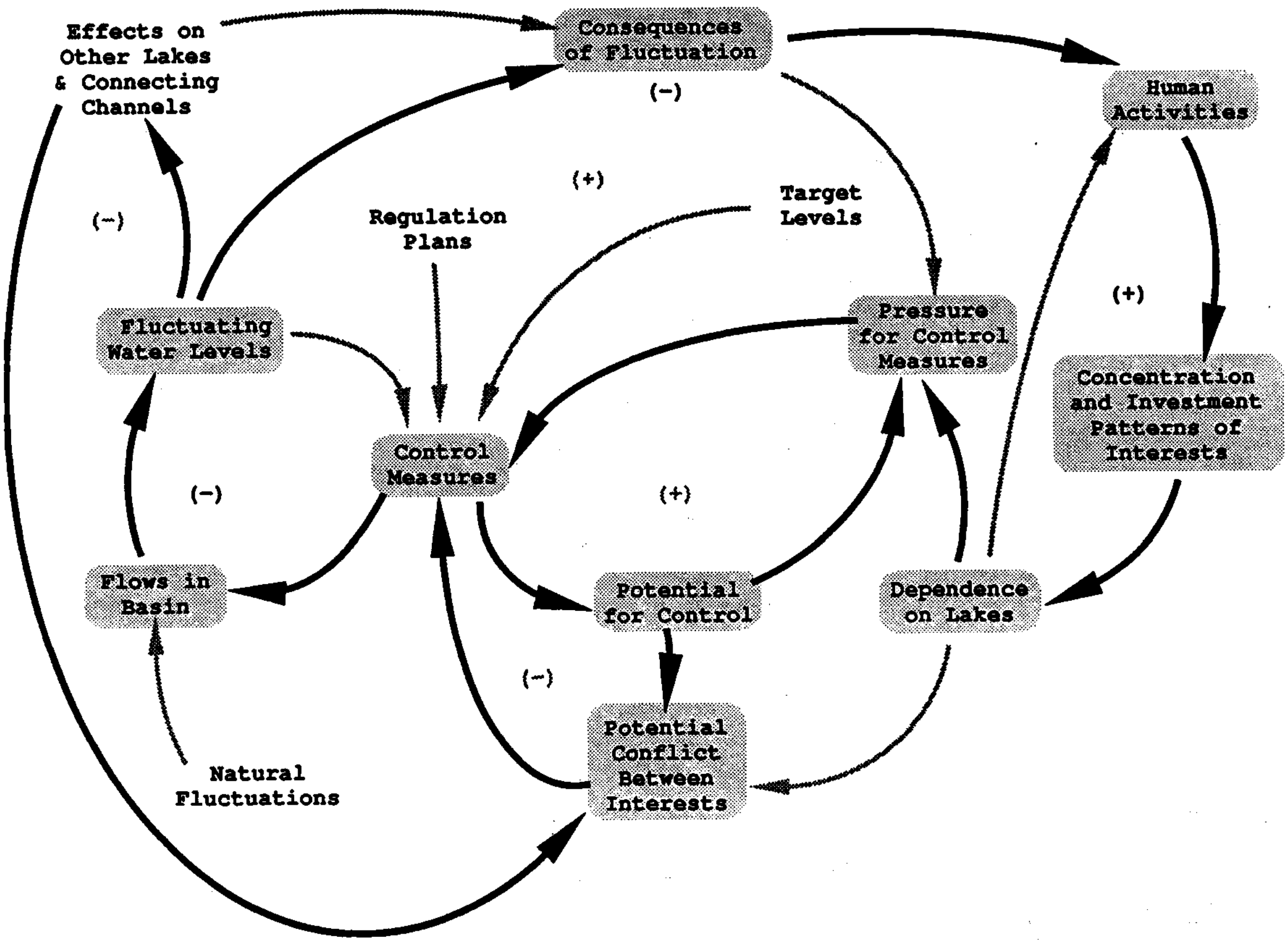

Figure 5: Certain feedback loops may intensify pressure for control measures as the potential for control and dependence on the Lakes increases. Increased conflict between interests, however, may work to prevent greater use of control measures.

3.7 Summary

o The Great Lakes are unique source of fresh water, in that, given the current level of consumptive and non-consumptive use, the storage is sufficiently large to insure an uninterrupted supply of water through any variations in basin supplies that could occur under our present climate and to allow a very long lead time to adjust consumptive use in the event of a climate change that drastically reduced basin supplies.

o Fluctuating water levels are a necessary consequence of the storage function of the Great Lakes. In addition, water levels fluctuate in response to storm events.

o Water level increases in response to storm events can be forecast with reasonably good accuracy, although this capability is not currently exploited in all lakes to the extent possible. Such forecasts could be very valuable in triggering emergency responses to storm-related high water events. Long-term lake level forecasts are reasonably reliable up to about six months. These can be very valuable for triggering responses to high and low lake levels that require longer lead times, such as dredging or construction of dikes.

o The knowledge base and data exist to estimate probabilities of lake level extremes resulting from all causes, including climate. To date such estimates have not been made. Well-developed strategies also exist for risk-based design of lakeside facilities. These strategies would account for the probability distribution of lake levels, the uncertainties in the probability estimates, the damage associated with various lake level extremes, the cost of alternative designs, and the design life of facilities. To date such strategies apparently have not been used.

o Short-term water level fluctuations, which account for a significant portion of the total range of fluctuations, cannot be controlled. It is feasible to exert some control on long-term variations in lake levels through the use of control structures and we are currently doing so. However, artificial control of lake levels works against their natural buffering capacity. The operation of any new control structures would be hampered by the resulting loss of natural buffering capacity.

- The expansion of existing diversion structures, such as those at Chicago, would provide the opportunity to control high lake levels. Diversion could be particularly effective as a means of keeping lake levels below prescribed upper limits. However, diversion structures could increase pressure to divert water from the lakes during critical droughts and they are likely to raise strong political opposition.

- An alternative to human control of Great Lakes water levels is the intelligent siting and operation of activities that are vulnerable to lake level fluctuations. This can be facilitated by wise use of our ability to forecast and characterize statistically extreme lake levels.

- It is important to avoid pressures for control measures that can lead to increasing dependency on control, greater potential conflict, and the future possibility of overreaction that may increase rather than decrease fluctuations.

HUMAN ACTIVITIES AND THE GREAT LAKES

4.1 Diverse Interests With Differing Relationships to Levels and Flows

Human activities related to the Great Lakes are usually described in terms of a set of "interests" that have particular uses for the lakes. The most striking thing about these interests is their diversity. There are, of course, obvious differences. Thousands of riparian owners have properties on the shoreline compared with much smaller numbers of hydro-electric or thermal power plants. However, the power plants each represent a very large capital investment compared to the riparians' properties and have millions of people depending on them for a vital service. There are many industrial plants along the lakes, some of which use the lakes for transportation while others use the water itself as part of industrial processes or for the disposal of wastes.

These interests also differ significantly in how they are affected by fluctuating flows and lake levels. Some, such as shipping and hydroelectric power, do better with high levels and flows. Others do better at lower levels because they have a greater "margin for error" in escaping damage from storms. Certain users, including water and sewer facilities and industrial plants located on tributaries, are not affected by levels in the lakes, but depend on adequate flows in those tributaries for their operation.

There are more subtle differences among interests as well. Figure 6 reflects how interests might be affected by changing levels by graphing the "utility" (u) to these interests as a function of lake level (l). For shipping, utility varies very little within a broad range of levels, but drops off gradually as levels go down, since loads must be reduced in order to operate with shallower drafts, and then falls sharply at some level when there is insufficient depth for ships to operate effectively. At higher levels, there is some loss of utility as a result of swift currents in channels, impairment in unloading, and interference in the operation of locks.

Hydroelectric plants have a different relationship to levels, in which utility grows gradually within a range as greater flows are able to produce more electricity. A sharp decline occurs, however, when levels fall below design minimums and an equally sharp decline results at high levels, if plants are damaged.

While it is often convenient to think of interests as homo-geneous groups for purposes of discussion, there are significant differences within, as well as between, interest groups in how their activities relate to levels. Most riparian owners will experience constant utility over a range of levels, but will differ greatly in terms of the effect of low or high levels.

As shown in Figure 6, owner "a" may enjoy increased utility at low levels if he or she usually has a narrow beach at mean levels and a wide beach at low levels. Owner "b," however, may suffer sharply lower utility at low levels if they have a boat dock adjacent to their property or an unsightly protective structure that is exposed at low levels. While many owners will suffer problems when static levels are high, owner "c," whose house sits on a high, non-erodible bluff, will not suffer any loss in utility.

Owner "d" may suffer ill effects of high levels sooner if his property is in an area that is vulnerable to the effects of storms. An owner on an erodible stretch of shoreline may suffer greater rates of erosion on his property as levels rise initially, but will continue to have some erosion even after levels go down.

Municipalities and large industrial users of water have a relationship to levels that is different from other interests. These can also differ greatly among users within this group. Utility tends to be constant within a broad range of levels or flows, but may drop off gradually at lower levels as the user must contend with reduced quantities and, possibly, reduced water quality. Plant "e," however, may suffer a very sharp decline in utility if its intake pipe is suddenly above the water level or if it is attempting to discharge contaminated water into a tributary whose flow has fallen below the rate for which the plant was designed. At high levels, users may suffer a loss of utility from damage that can result, but plant "f," built a safe distance away from and above the water would escape such damage.

The relationship between particular interests and flows and lake levels depends on a number of other factors besides that interest's basic use of the lake. These include:

- o Physical Location: Proximity to shore, elevation, orientation of prevailing winds and storms, proximity to tributaries, mean depths offshore, etc.

- o Nature of the Shoreline: Erodible vs. non-erodible, presence of beaches, protective structures, or functional structures (e.g., docks).

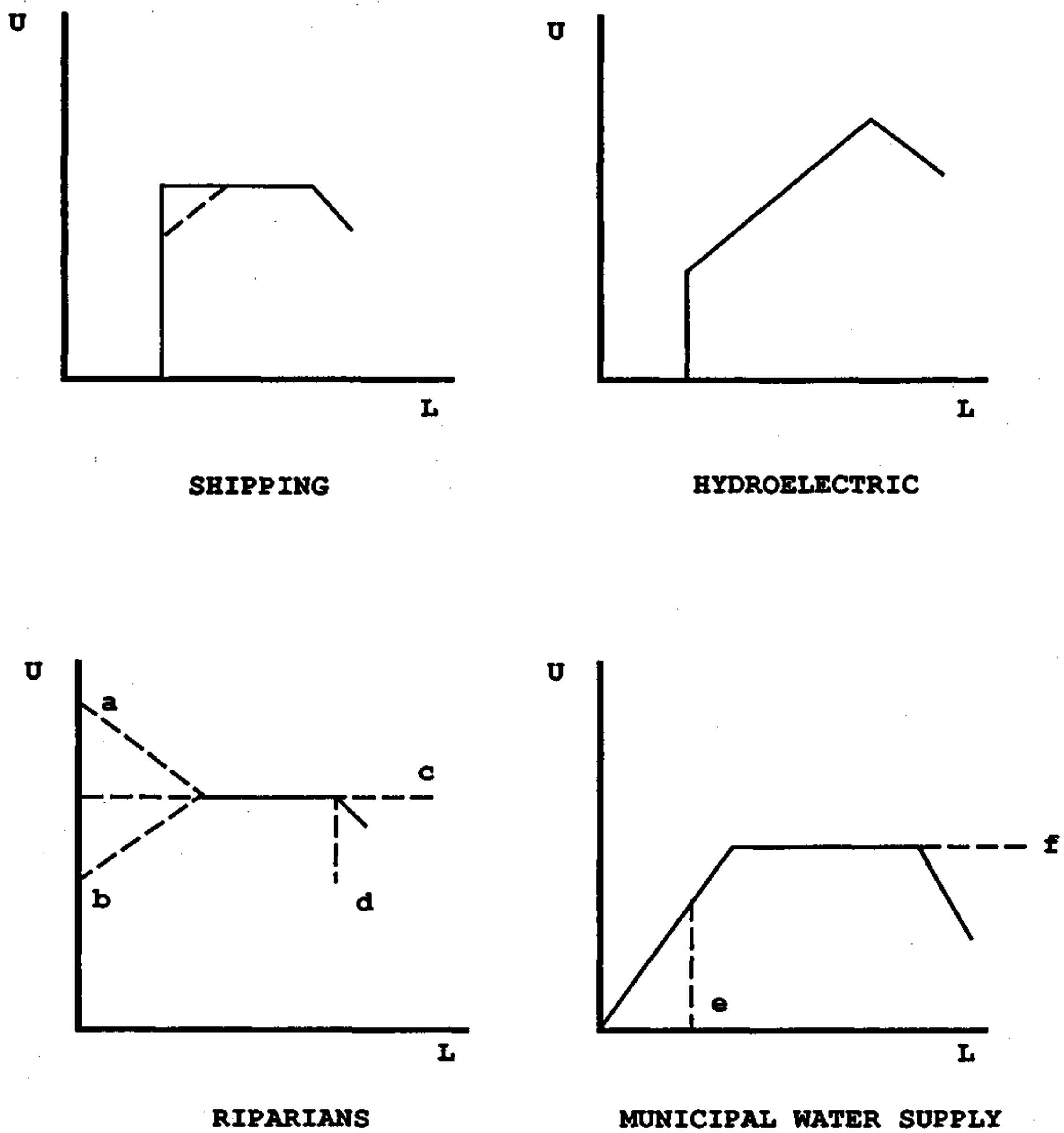

Figure 6: Relationship of various interests to lake levels ("utility" as a function of levels).

o Technology Utilized: Shallow draft ships and industrial plants that recycle water will do better in low flow, low level situations.

o Political Jurisdiction: The effects of applicable laws, permitting processes, taxes, etc.

o Economic Environment: Demand for particular products, costs of factors of production including water, and competition from other regions.

o Proximity of Other Uses: Shoreline property near a chemical plant will be less desirable than in an unspoiled setting.

o Attitudes of Particular Groups (e.g., toward nature).

These important differences, even within particular interests, make it difficult to reach agreement on the desirable direction for measures. This, in turn, makes it difficult to develop and implement global measures that might meet the needs of more than a minority.

4.2 Human Activities Are Dynamic

Even if it were possible to characterize the diverse set of interests related to the Great Lakes at any point in time, the picture would soon be out of date, as the interests are constantly changing. Some of the most significant changes are due to forces independent of the lakes and their levels, such as foreign competition forcing the closure of an obsolete steel mill. Yet, they can have a major impact on the lakes, especially if they affect an industry that has an important presence in the Great Lakes Basin. Measures justified on the basis of a particular set of interests at a point in time may, themselves, become obsolete over time.

Other changes are closely related to the lakes, their levels and flows within the basin, and the quality of the water they contain. Although the interests are not always aware of it, their behavior represents a dynamic process of interaction wih the rest of the system. This complex pattern of interaction makes it more difficult to understand how hydrological changes and control measures will affect particular users in the long-run. Through their actions, the interests affect:

o Levels of the lakes, flows within the basin, and water quality.

o The consequences they experience as a result of hydrological variations. Their experience with fluctuations is determined by decisions their members make:

- In the short-term, by adjusting their operations to fluctuating levels and flows.

- In the long-term, by investing in facilities that have differing degrees of vulnerability to fluctuations.

- In the long-term, by deciding whether to locate in, leave, expand, or contract operations in the Great Lakes Basin.

o Other interests.

o The loosely knit governance system that affects various activities in the Basin.

o The regional and, in some cases, national economies.

Interests' interactions with their environment are affected by their perceptions as well as reality. The absence of information about the behavior of the lakes causes perceptions to take on special importance. Lacking a broader context for their perceptions, interests respond to their own perceived self-interest in calling for action and evaluating proposed measures. Without a broader context, interests do not fully understand the implications of what they are demanding for the system as a whole or sometimes, even for themselves.

Interests do not function in isolation from one another. They can come into conflict about measures and they can also form coalitions and work toward common objectives, notwithstanding their individual goals. For example, certain interests may favor higher levels because they depend on lake shipping, or hydroelectric power, even though higher levels might not be what each would prefer.

4.3 Human Activities and Vulnerability to Fluctuations

The manner in which human activities are carried out determines vulnerability to fluctuations and the magnitude of the consequences. Vulnerability, however, is not merely a passive quality of human activity, a set of risks to be endured, but is the result of deliberate human decisions. As noted earlier, where and how people choose to build structures will affect their vulnerability to fluctuations. How people use water will affect their vulnerability if reduced flows or degraded quality affect its availability.

To understand how human activities determine vulnerability to fluctuations, it is necessary to expand the "human activities" cluster in the preceding diagrams to understand how each interest makes decisions and interacts with other interests and the governance structure. Figure 7 shows that vulnerability is affected by:

- o The manner in which investment decisions are made by interests.
- o Interests' decisions to locate in the basin.
- o Certain types of measures.

Investments made without attention to fluctuations and high concentrations of interests that have made poor decisions will produce larger total vulnerability. Subsequent sections examine how the decision-making behavior of interests affects their vulnerability.

Measures are the other key influence on vulnerability. As shown in Figure 7, damage suffered by interests will cause them to pressure governments for measures. These measures include actions designed to control the fluctuations themselves, build protective structures and mitigate consequences of fluctuations, and enhance adaptability to fluctuations in a manner that reduces vulnerability. These, in turn, affect investment behavior and the consequences of fluctuations for human activities. Some of these effects are obvious, such as low interest loans for disaster relief that reduce the cost of the damage caused by fluctuations. Others are more subtle. Protective measures built with government assistance reduce vulnerability to high levels and storms, but can contribute to increased vulnerability, by enabling people to feel more secure and encouraging increased density of development closer to the water's edge.

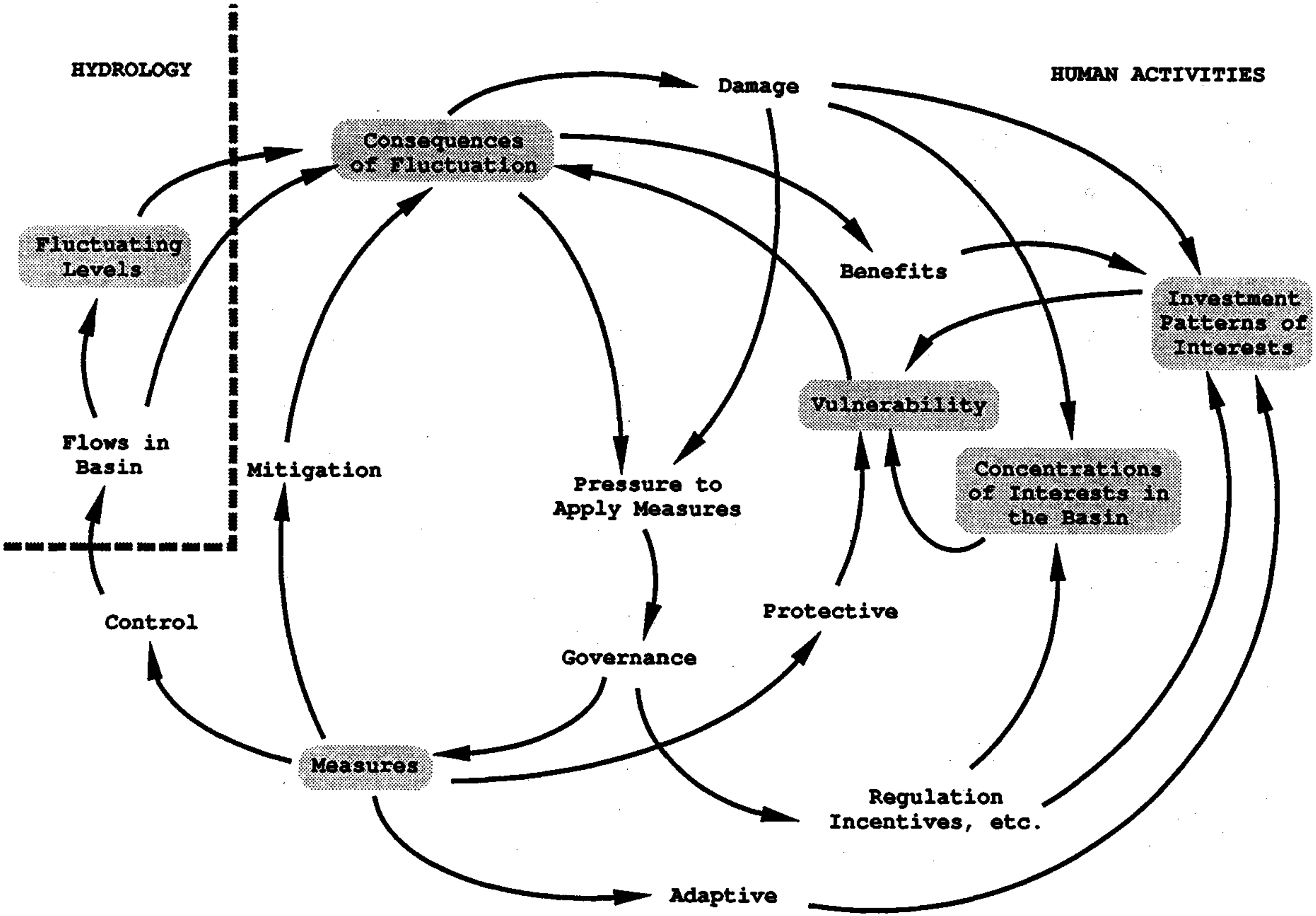

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Figure 7: Consequences of fluctuations are a result of both fluctuations themselves and vulnerability to fluctuations. Measures can affect the magnitude of fluctuations, their consequences, and vulnerability to them.

Figures 8, 9, 10, and 11 examine the behavior of the various interests as they affect vulnerability, in more detail. Rather than focus on a particular interest such as riparians, shippers, or hydroelectric power producers, these figures present a set of relationships that should hold true, in general, for all interests (although their relative importance will vary among interests, given the diversity discussed earlier).

As shown in Figure 7, vulnerability to fluctuations is principally influenced by investment and location decisions of interests, both of which produce change gradually. Figure 8 touches briefly on the (relatively limited) options for responding to fluctuations in the short-term. Figure 9 examines investment decisions of interests and how they can be influenced by two key criteria: Perceived potential damage from fluctuations and maximization of utility and profits.

Figure 10 examines some feedback loops affecting investment decisions that can bring these criteria into conflict and lead to increased vulnerability overtime. Figure 11 shows how the development process affects concentrations of interests and, if not balanced by ecosystem considerations, can also increase vulnerability.

4.4 Short-Term Responses to Fluctuations -- Limited Opportunities to Affect Vulnerability

Decisions by interests that affect the consequences of fluctuations are made in different timeframes. In the short-term, they are usually only able to adjust their operations to deal with the consequences of changing levels. Figure 8 illustrates this process of adjustment.

Each has preferred modes of operations reflecting the basic nature and economies of their "activities," the mix of technologies they employ at any point, and the capacities of their facilities. Thus, shipping lines prefer to operate their vessels fully loaded and riparian owners want to get full use of their properties, including recreational facilities.

The mix of facilities, technologies, and other characteristics is referred to in Figure 8 as the asset profile. The asset profile has an important effect on the dynamics of consequences because it only changes gradually in response to new investments. The vulnerability created by investments lasts for many years due to the long lives of these assets.

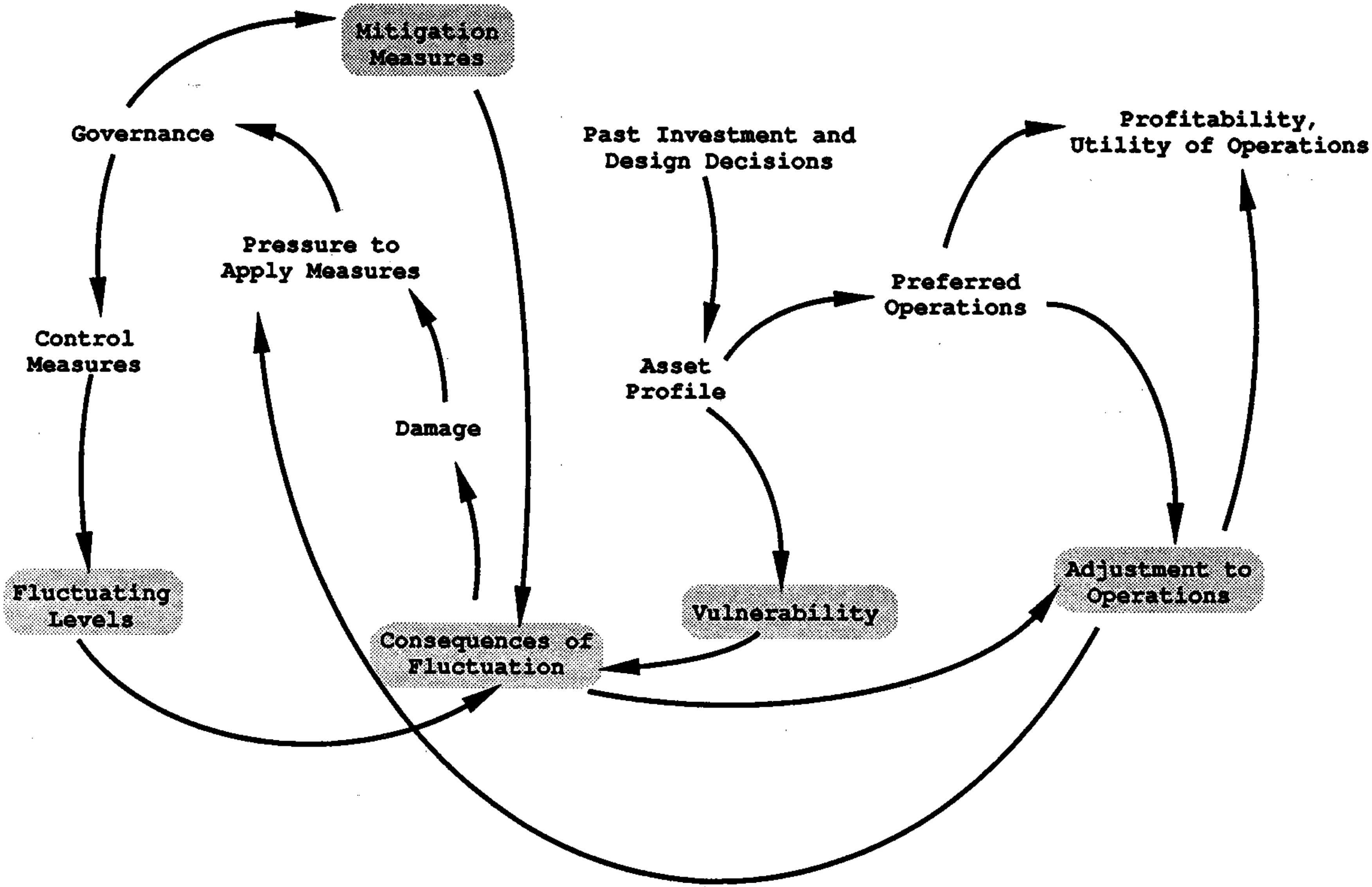

Figure 8: Short-term responses of interests to fluctuations

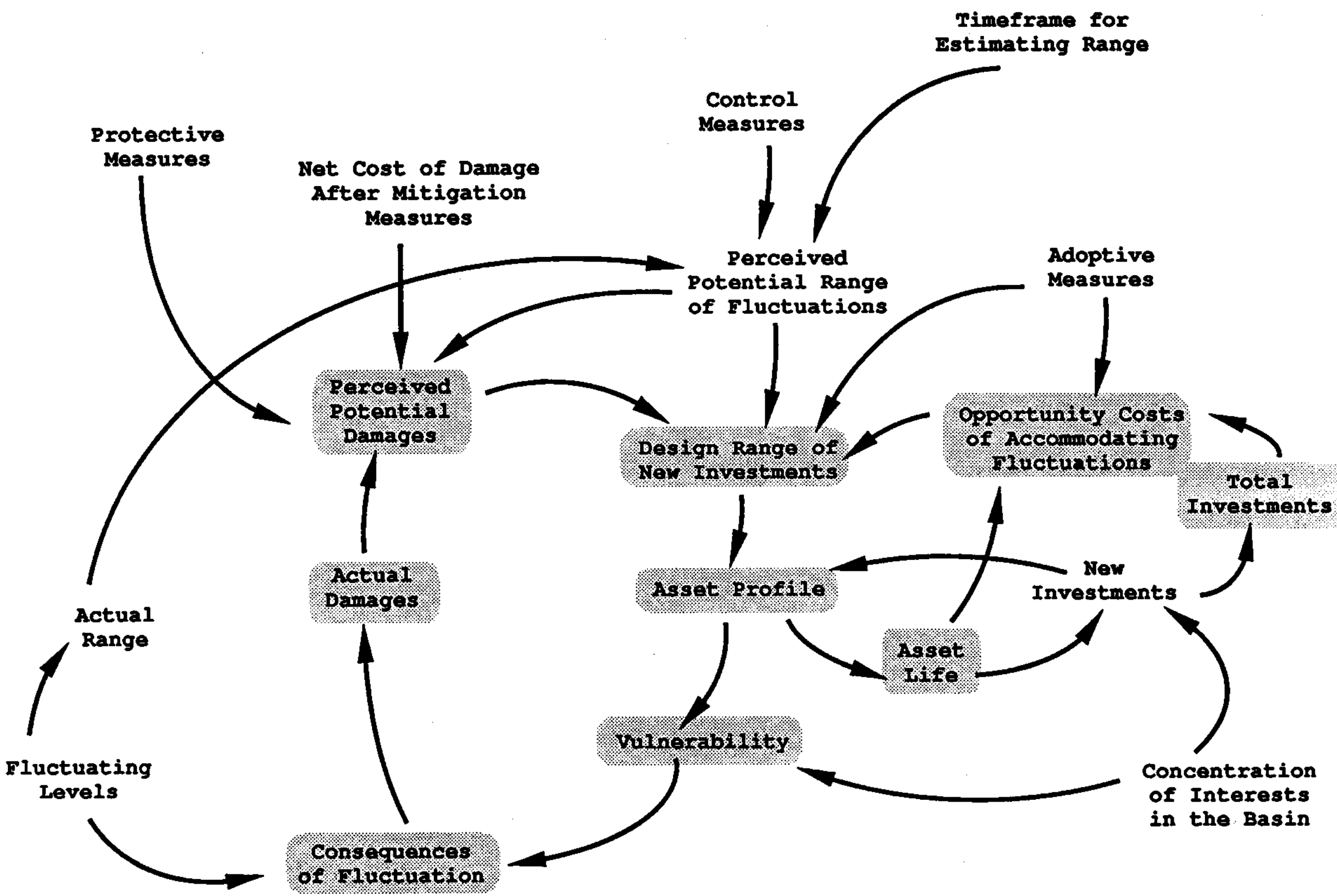

Figure 9: Effects of long-term investment patterns on vulnerability

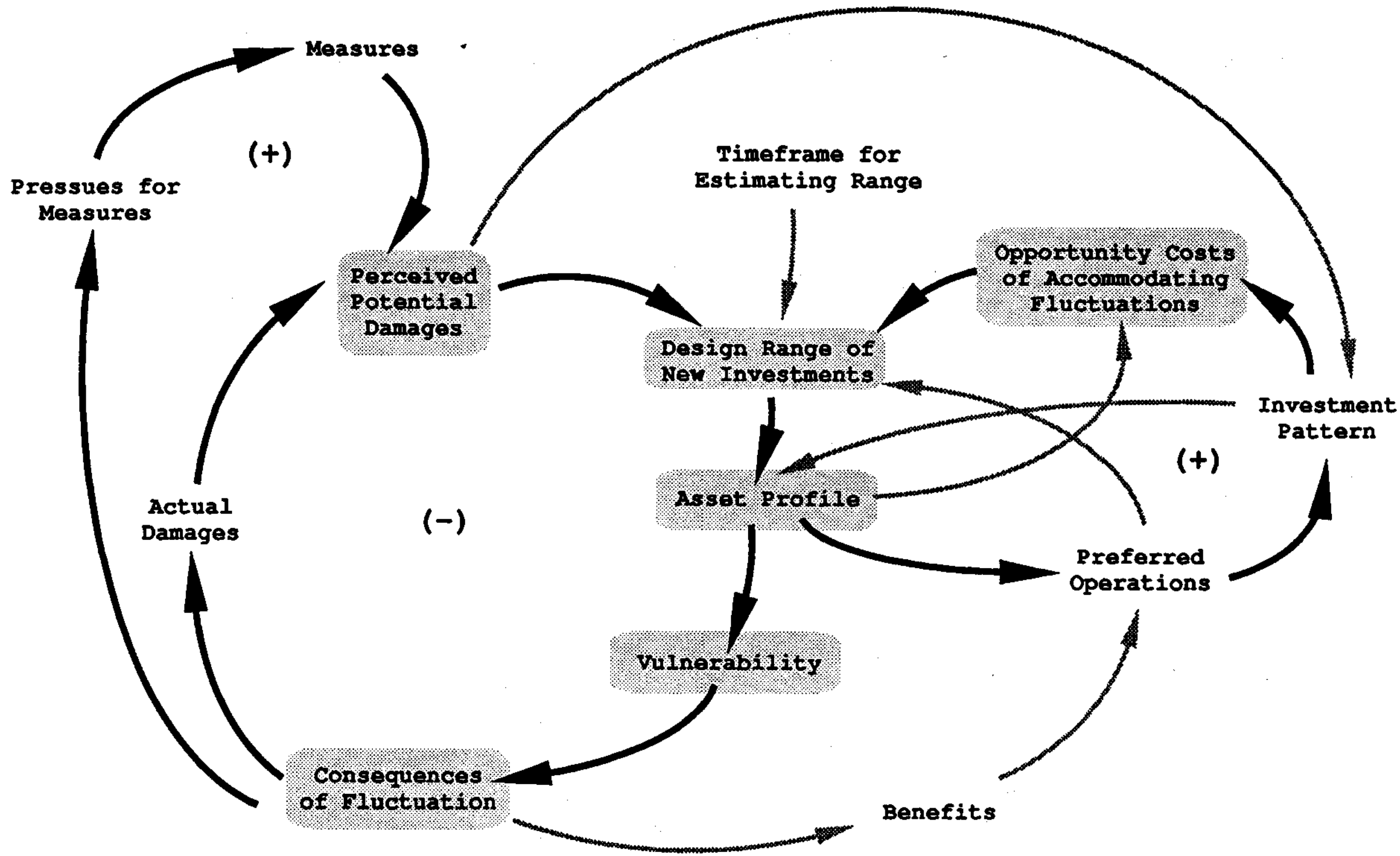

Figure 10: Certain feedback loops may cause interests to inadvertantly increase their vulnerability. Measures can contribute to increased vulnerability if they reduce the risk as perceived by interests and cause them to use a narrower design range for new investments over time.

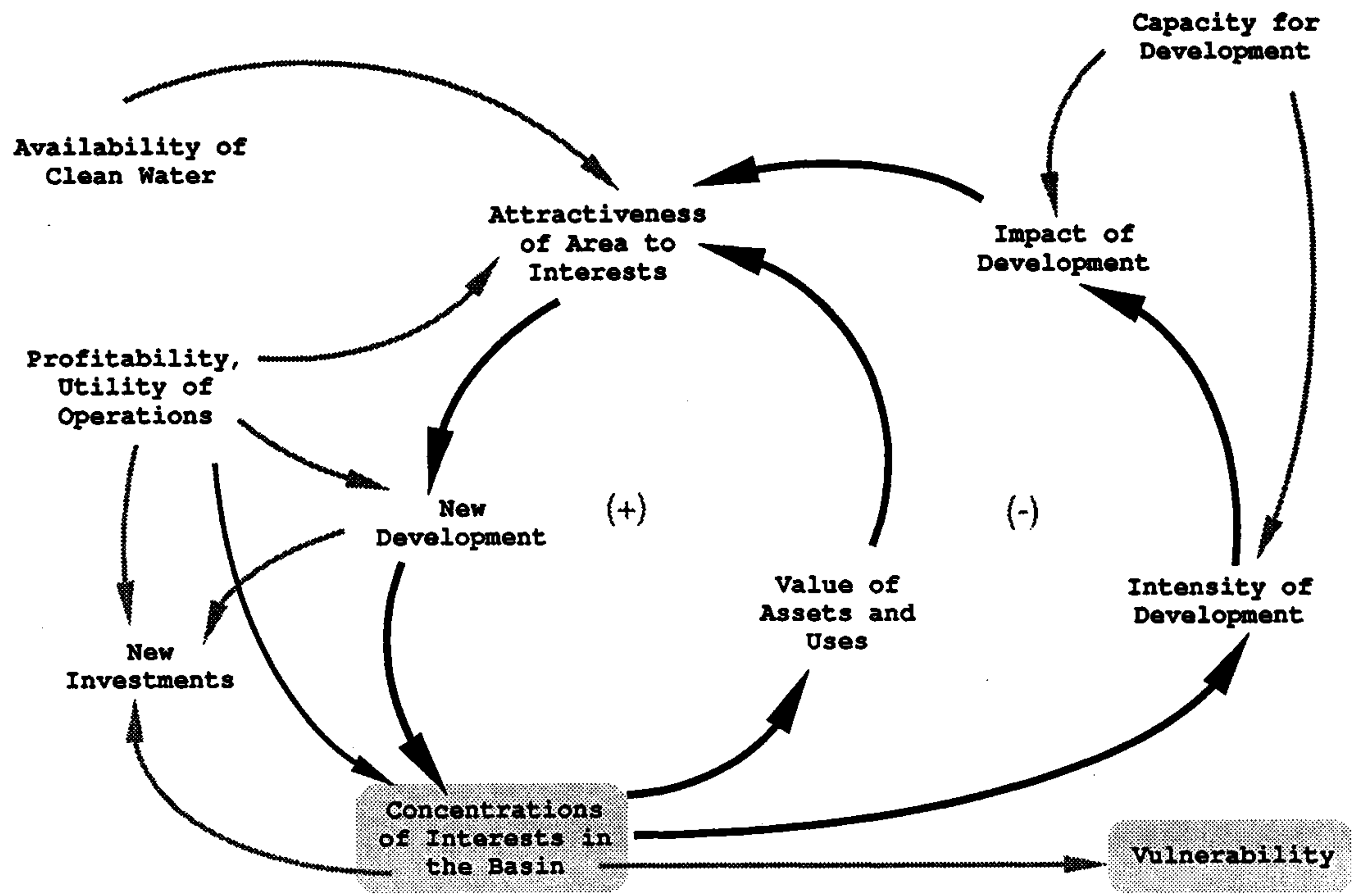

Figure 11: Concentrations of interests in the basin increase as part of the development process which may slow down as the impact of development effects the area's attractiveness.

Actual operations, as opposed to preferred, will reflect a number of forces, including regulatory pressures and economic conditions, as well as adjustments that have been made as a result of fluctuations. At low levels ships will have to operate at less than full capacity or may not be able to use certain harbors. Riparians will have narrowed beaches when levels are high and may sustain damage if storms are imposed on these high levels. The degree of adjustment required is a function of the deviation of levels and flows from ranges preferred by the interests, an interest's sensitivity to those fluctuations, actual damage created by extreme fluctuations, costs of the difference between optimal and actual operations, and various kinds of mitigation that can be achieved. These adjustments are as much a part of the consequences of fluctuations as more dramatic impacts such as storm damage.

In the short run, interests are relatively limited in their responses to fluctuations. The actions they take and the help they receive is designed to reduce economic and/or physical damage. Emergency responses can reduce the cost of fluctuations (e.g., low-interest disaster loans), but do not affect vulnerability unless they also produce a shift in investment patterns. Vulnerability to damage can be modified to a limited extent, but is generally a function of decisions made at critical points, such as the design of new facilities, and cannot easily be varied the short-run.

This limitation may cause interests to focus their energies on finding "someone else" to solve their problem. To the extent that they believe that fluctuations can be controlled and that his is, in fact, the nature of the problem, they will look to the governance structure for control measures. If responses by the governance structure reinforce this belief, the subsequent focus will be on control measures.

4.5 Effects of Longer-Term Investment Decisions on Vulnerability

The sensitivity of interests to hydrological fluctuations, their resulting vulnerability, and the cost of adjustments they must make, reflects their pattern of investment, the mix of technology, and scale of facilities in place, and the location of investments. Shipowners with shallow draft vessels will have to make smaller adjustments as levels drop than those with deeper draft vessels. Industrial plants that use large quantities of water and are situated on tributaries with reduced flows will have to make larger adjustments than those that have invested in processes that recycle water and have relatively small use requirements. Riparians with cottages in vulnerable shoreline areas will have to make the greatest adjustment to fluctuations, especially when they are extreme.

As indicated earlier, the way in which interests make investment decisions will have a major effect on their vulnerability to fluctuations. As shown in Figure 9, the magnitude of investments made in the Great Lakes Basin by interests is a function of the concentration of those interests in the Basin and their willingness to invest. The technology and scale of new investments causes the interests' asset profile to shift over time.

4.5.1 Design Range of New Investments as a Key Determinant of Vulnerability

A key aspect of investments made by interests is the range of fluctuations they are designed to accommodate. This design range may have different meanings: For a structure built on the shoreline, it may mean the level that the lake can reach without doing significant damage or interfering with the structure's intended use. For ships, the design range would be the minimum levels needed to permit passage on the routes where they are used. For sewage treatment plants or industrial plants discharging into a tributary, the design range could be the volume of flow necessary to take discharges occurring under normal operations and still remain within applicable water quality standards.

The design range is a function of a number of factors. The perceived potential range and damage may cause interests to build in a larger design range to accommodate the range of fluctuations likely to occur. Poor information about fluctuations may cause interests to underestimate the potential range of fluctuations or fail to consider potential fluctuations in their designs. Further, the presence of particular control or protective measures may cause interests to feel more secure from the consequences of fluctuations. Mitigation measures may inadvertently help to reduce the design range by lowering the anticipated cost of damage to particular interests.

A problem that can occur, possibly as a result of poor information, is that there is a mismatch between the life of an asset and the timeframe used to estimate the potential fluctuations to which it will be subjected. Design of major facilities generally tries to optimize performance based on considerations such as largest economical capacity, most efficient technology, lowest operating expenses, and longest service life. Unless hydrological fluctuations are an explicit focus of the design effort, insufficient data may be used as the basis for designing the facility. As a result, fluctuations are likely to exceed design tolerances and produce significant costs due to damage and suboptimal operations.

An egregious example of this phenomenon is a marina built when levels were at their highest that had boats sitting in mud when levels started going down, even when the levels were still well above their historical mean. The developer of this marina used a very short timeframe in anticipating the effects of fluctuations. This particular problem could worsen, given the current uncertainty about climate changes and the possibility of very low flows and levels that some foresee. While no one knows how soon and by how much climate will change, it is likely the some major changes will occur within the 40-50 year useful lives of facilities now being designed and built.

4.5.2 Opportunity Costs and the Pressure They Exert on Design Range

Design decisions made by the various interests contain trade-offs that produce opportunity costs as design ranges are made larger. For example, large setbacks from the shoreline can practically eliminate the possibility of damage from fluctuating water levels. However, these setbacks have an opportunity cost in terms of not being able to use valuable shorefront property. Similarly, shallow draft ships would almost never have a problem navigating the lakes, no matter how low levels fall, but would sacrifice much of the efficiency and profit potential that is possible with larger ships.

Design decisions should ideally balance efficiency and reduction of vulnerability in a way that minimizes total cost (cost of operation plus probable loss due to adverse effects of fluctuations) over the life of the asset. The existence of these opportunity costs makes interests resistant to enlarging design ranges, especially if the benefits of doing so are not clear.

To balance these considerations, interests need better information on probable losses due to fluctuations. Interests also respond to actual costs they would have to bear rather than theoretical costs borne by "society." A property owner who can get a public agency to build shore protection at no cost to him could not be expected to opt for a larger setback if it entails an opportunity cost.

4.5.3 Feedback Effects That Cause Investments to Increase Vulnerability

The relationships in Figure 10 depicts how vulnerability to fluctuations can continue increasing despite the fact that interests are suffering damage. As shown, there are feedback loops that act to reduce potential damage by causing design ranges to reflect past damage and discourage investments vulnerable to fluctuations. However, these loops are weakened by the intermittent nature of fluctuations and the damage they cause. Perceived potential damages are often less than the actual risk because people have poor information about past damage and/or a perception that various measures will protect a contemplated investment.

Arrayed against this fuzzy picture of potential damage is a much clearer picture of the opportunity costs an interest must bear by accommodating a larger design range. Interests have a clearer sense of their opportunity costs because these costs are a part of the everyday economics of the interests' activities. Shippers know how much it costs them to use smaller ships, but are less certain how likely it is that low levels will create problems for larger ships.

As shown in Figure 10, there is a loop that causes opportunity cost to become a more important factor in investment decisions over time. The asset profile that develops will influence the preferred mode of operations. Later investment decisions then respond to that preferred mode and reinforce the original asset profile.

Large ships, for example, usually have lower costs per ton than small ones. When large ships are introduced, rates are lowered and shippers adding to their fleets are forced to acquire larger ships in order to remain competitive. As more shippers acquire larger ships and drive rates down further, the opportunity cost of operating with smaller ships increases, as does the incentive to acquire larger ones. The risk of levels falling to the point that larger ships must operate partially loaded, or not be able to operate at all, may seem insignificant compared to the very real competitive pressures that exist.

This loop, because it involves better information and, in some cases, net economic gain for interests, will tend to dominate the loop through perceived potential damage. While each individual decision-maker assumes a limited risk that he may deem acceptable, the cumulative effect of these influences is continued growth in vulnerability for society as a whole. Not only does this mean large costs when levels reach extremes (often borne by the taxpayer under one program or another), but also pressure for measures that have their own high costs.

The pressure for measures will increase with vulnerability and resultant damage. Working against this pressure for more measures, however, is the fact that the pressure is greatest when levels are at their extremes and is, therefore, intermittent in nature. This helps to explain why more measures have not already been implemented even though there have been repeated instances of extreme levels over the years. As overall vulnerability increases, however, these pressures are likely to become great enough to result in action.

An important aspect of the dynamic involved in such cases relates to the fact that these loops, although reflecting decisions made by individuals, create a cumulative vulnerability with costs borne by the population as a whole. These include the cost of damage due to fluctuations, the cost of compensation in various forms, and the cost of measures interests demand to protect them from damage. Because there is no one agency keeping track of this cumulative vulnerability, there is no source of feedback to resist its growth with appropriate adaptive measures.

4.5.4 Implications of Investment Behavior for Policy

What are the implications of these dynamics for policymakers and how far can/should government go? There are a number of reasonable things that could be done. For example:

- Better information for decision makers is clearly needed for overcoming the tendency to forget damage and place too low a value on it when making investment and design decisions. These decision-makers include lenders, insurers, and municipal code enforcement officers, as well as the interests themselves.

- Develop incentives that influence investment decisions. A government agency faced with a great expense for enlarging channels might find it worthwhile to spend a lesser amount of money subsidizing the acquisition of smaller vessels instead. This would be similar to the way in which electric utilities are now investing in conservation projects for their major customers in lieu of investments for new generating capacity.

- Avoid incentives that send the wrong message. Flood insurance that permits repeated rebuilding on the same site will contribute to increased vulnerability.

4.6 Concentrations of Interests in the Basin

The other factor that affects vulnerability is concentration of interests in the Basin. The presence and concentration of particular interests in the Great Lakes Basin is itself dynamic and subject to change based on a number of interrelated factors. As shown in Figure 11, concentrations of interests in the basin grow as a result of the processes of economic development in a positive feedback fashion.

Development of vacation cottages along a section of shoreline will create a demand for recreational facilities and public infrastructure that, once provided, will stimulate additional development. As economic development in an area continues, the value of particular assets increase and attracts additional development. Other relevant factors, such as the availability of clean water can also affect the attractiveness of the area to interests. The profitability or utility of past investments in the area will have an effect as well. Having to absorb opportunity and/or damage costs due to fluctuations will reduce the area's attractiveness.

These growth processes affecting interests are resisted by forces that include competition from other interests for land, water, employees, and other resources and regulatory actions. The feedback that resists development and concentrations of interests may also result from adverse impacts that occur when development becomes too intense. This is a function of land and water resources available, as well as particular site-specific characteristics.

The level of development in an area and the concentrations of the various interests is a result of the balancing of these feedback loops. Weak loops, that might resist overdevelopment, in addition to permitting unfortunate environmental consequences, may allow concentrations of interests to grow in a manner that increases vulnerability. This will be especially true if greater intensity forces development into more vulnerable places. Better information about potential hazards due to fluctuations will help to slow growth and keep it from vulnerable areas.

Just as interests interact with levels and flows, with the natural ecosystem, and with each other, they also operate within a context of governmental and quasi-public agencies that regulate uses of the lakes and/or help to mitigate consequences of fluctuations. The governance structure has a broad influence on each interest and can be a major determinant of an interest's development in a region. The governance structure can also help to maintain the balance between the positive and negative feedback processes shown in Figure 11 and help to constrain vulnerability due to concentrations of interests. The role of governance will be discussed in a later section.

Effective planning of development has great importance for the problem of fluctuating water levels precisely because it affects vulnerability through concentrations of interests. Existing land use patterns help to determine current vulnerability and the consequences that occur. These patterns also restrict options in the set of measures that can be used to prevent or reduce consequences (e.g., shore protection in areas with high building density). However, development planning is a key tool for affecting future vulnerability and options for dealing with fluctuations. As indicated earlier, planning should keep development within the capacity of areas to accommodate it, as well as out of especially vulnerable locations in order to reduce vulnerability in the future.

4.7 Social Learning

There is one other, "higher order," human activity that can have an important bearing on whether the consequences of fluctuations are dealt with effectively. This activity can be called "social learning." It involves a shift in mindset -- from viewing the problem as a set of "natural disasters" and the interests as "victims" whose only recourse is to appeal to governments for assistance -- toward a more balanced view. This balanced view would include a perceived need to protect assets against storm damage and other adverse consequences. However, it would also include the recognition that human activities contribute to vulnerability and that this, in turn, requires careful attention to minimizing vulnerability when making location and investment decisions. Figure 12 shows how the perception of the problem can affect the relative emphases on two different responses to the consequences of fluctuations.

The public's perception of fluctuations may change in response to information in the news media and from government agencies and advocacy groups. A shift may also occur based on experience. People who depend on a single type of measure may learn the need for a more balanced response if they suffer consequences despite the presence of their preferred measure. This learning due to experience can be enhanced with the appropriate information and incentives.

This shift in mindset may be essential for implementing a balanced set of measures, especially one that includes adaptive measures to help interests reduce their vulnerability. Providing education in support of such a shift is therefore an important function.

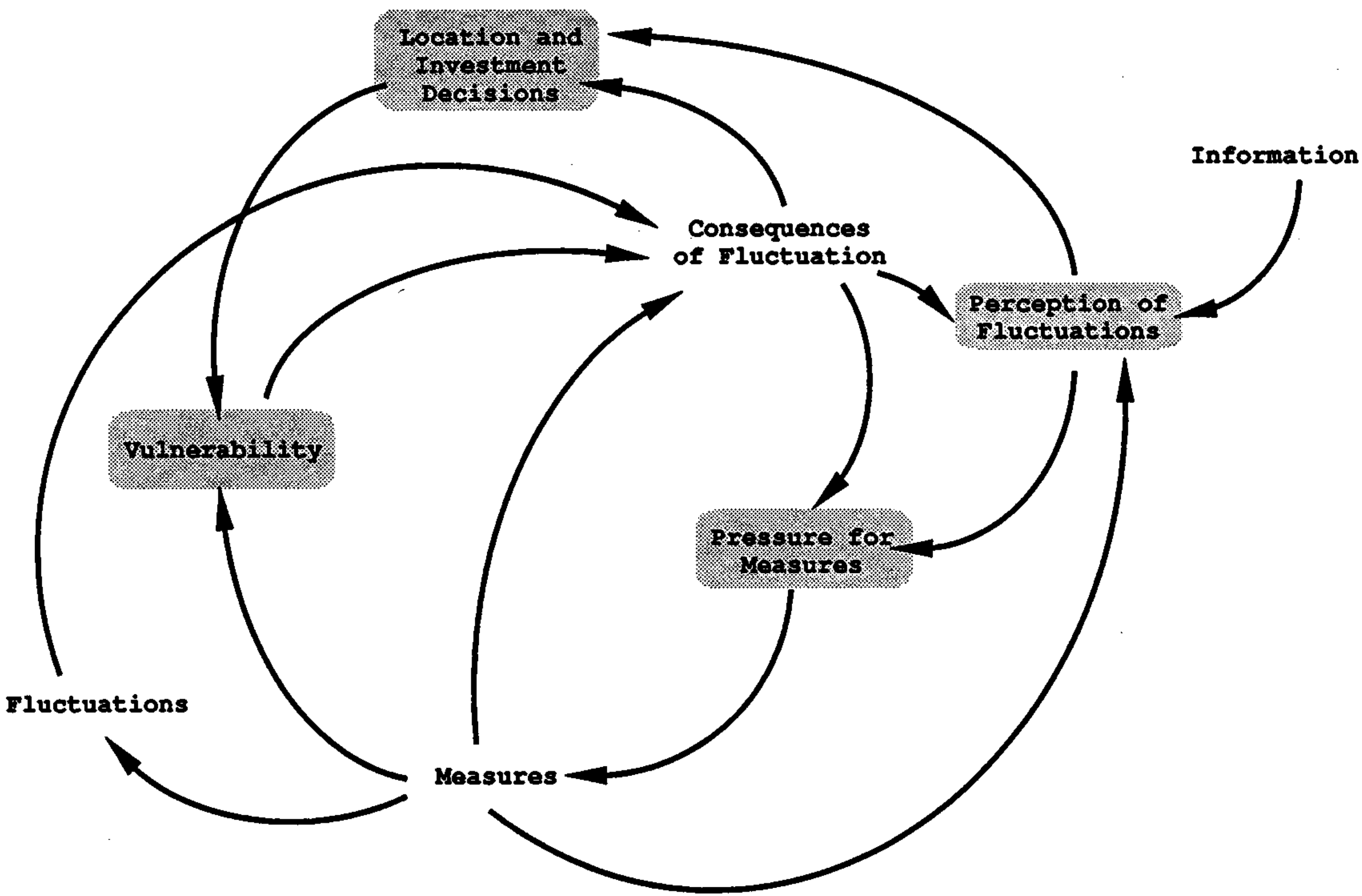

Figure 12: A shift in perception about fluctuations, aided by better information, may cause people to rely less heavily on pressing for measures and adopt a more balanced view that includes more attention to their own location and investment decisions (to reduce vulnerability).

THE NATURAL ECOSYSTEM AND ITS RELATIONSHIP TO FLUCTUATIONS

5.1 Interaction of Natural Ecosystems, Hydrological Fluctuations, and Human Activities

The natural ecosystem interacts with both human activities and hydrological variables in a manner that adds to the set of relationships embodied in the system. The relationships with natural ecosystems are important for several reasons:

- Protection of the integrity of the natural ecosystem has become an accepted principle underlying international agreements governing the water quality of the Great Lakes. Measures for dealing with consequences of fluctuations that disturb the integrity of natural ecosystems would be inconsistent with these existing agreements.

- Natural ecosystems play an important role in buffering human activities against the effects of natural fluctuations. Measures that reduce this buffering capacity work at cross-purposes to reducing the consequences of fluctuations.

- Some types of measures can affect natural ecosystems. Certain ecosystems, such as coastal wetlands, depend on fluctuating levels for their actual existence. Overly tight control of fluctuations would endanger these critical resources. Byproducts of certain measures, such dredging that stirs up contaminated sediments, can also harm natural ecosystems.

- Natural ecosystems play a role in maintaining water quality, as well as being affected by reductions in quality. These ecosystems have many other valuable roles including those of wildlife habitat and providing esthetic experiences and economic benefits to man. Measures for mitigating affecting the consequences of fluctuations must protect these features.

Although not a focus of the current reference, water quality is part of the systemic context in which the consequences of fluctuations occur. Quality and quantity have a significant relationship, especially at times when flows and levels are low. Such low flows and levels may reduce the availability of water for consumption and poor water quality would exacerbate the consequences of low flows by making clean water less available and/or increasing treatment costs. Low flows in tributaries could also reduce their capacity to dilute sewage, toxic wastes, and nutrients from agricultural runoff and absorb thermal discharges from power plants. This would have an adverse effect on water quality in these areas. This two-way interaction of quality and quantity can create serious consequences for some communities, especially at particularly vulnerable locations.

5.2 Wetland Ecosystems: An Example

Figure 13 highlights how natural ecosystems, human activities, hydrological fluctuations, and water quality interact. Wetlands are used as an example to show how natural ecosystems, in general, affect and are affected by these interactions.

The natural ecosystem interacts with both hydrological variables and human activities in a manner that adds another layer of complexity to the system. This interaction also links quality and quantity concerns in a manner that needs to be better understood in order to deal effectively with fluctuations.

Fluctuations are essential to maintaining wetlands around the shores of the lakes. These wetlands perform a number of valuable ecological functions. Wetlands help to maintain the balance of species and activities in near-shore areas. While these areas represent only a small fraction of a lake's total area, they serve as critical "centers of organization" for the lake ecosystem.

As shown in Figure 13, wetland quality and area also affect the volume of fish production and moderate pollution and nutrient loading. This, in turn, affects water quality.

Excessive nutrient loading, on the other hand, overwhelms this capacity to handle nutrients and produces algal blooms that rob plants of sunlight and fish and other animal life of oxygen.

Human activities affect the near-shore ecosystem in a number of ways, producing stresses that reduce its natural capacity to maintain species diversity and productivity. Degradation of water quality caused by these stresses also affects the consequences of low levels and flows.

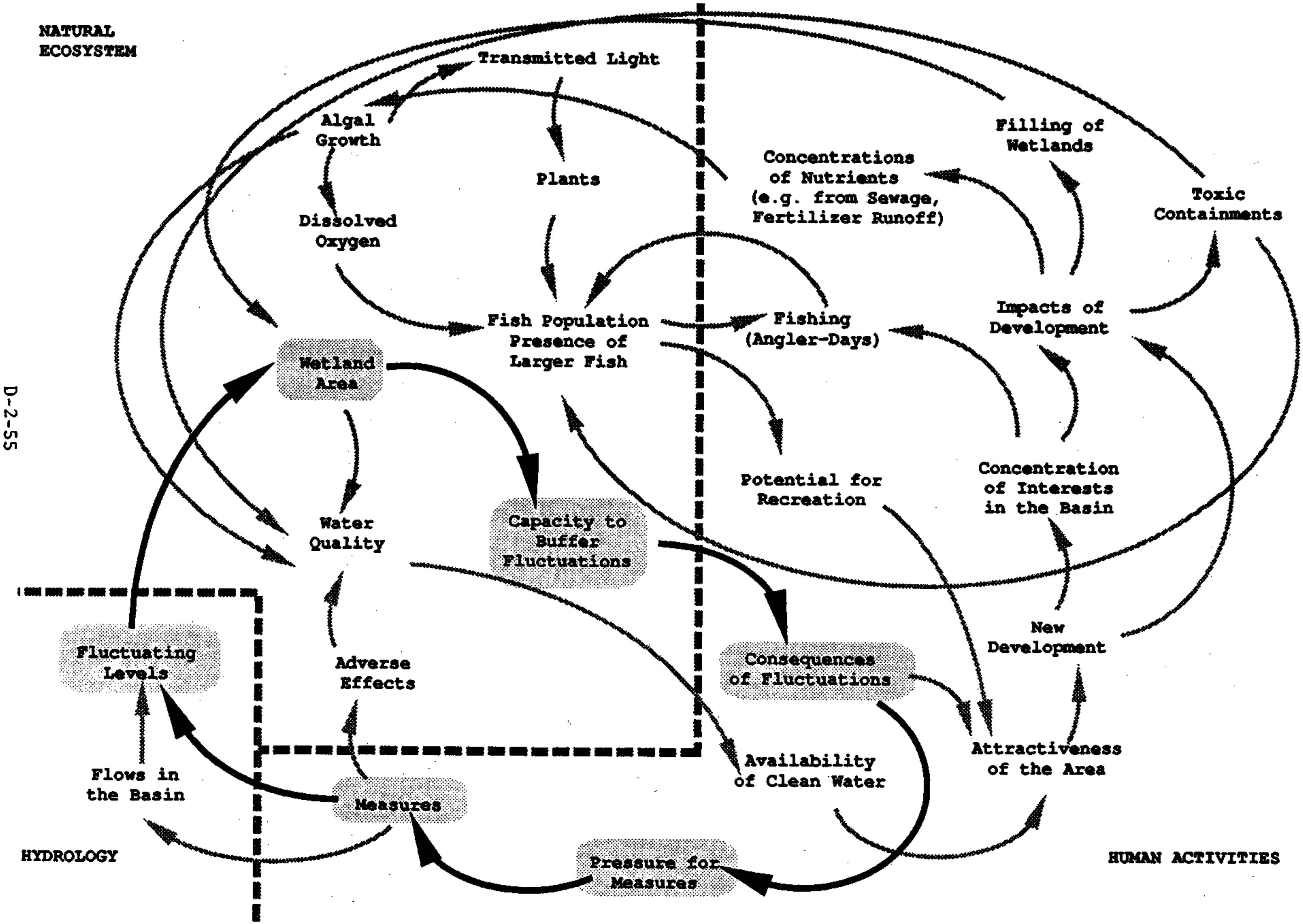

Figure 13: A key interaction between the natural ecosystem and the levels problem is related to the capacity of wetlands to buffer the effects of fluctuating levels.

Many different stresses, produced by various interests using the lakes, can affect the ecosystem. Agricultural practices, for example, can contribute to excessive nutrient loading which can produce algal blooms at certain times of the year. Thermal discharges from power plants may reduce already depleted oxygen levels. Filling of wetlands and dredging for recreational boat channels and marinas, and construction of housing on the shoreline may also damage fish habitats, as shown in Figure 13. These activities interact as well as having direct effects. Filling of wetland areas decreases their ability to moderate the increased flows of nutrients and toxic contaminants and higher concentrations result.

The interaction between human activities and the natural ecosystem goes both ways. For example, as Figure 13 suggests, if development in a particular shoreline community is not managed well, it can destroy the natural features that originally attracted development. Overfishing may reduce one of the resources that made the area attractive for recreation. Degraded water quality can also reduce the attractiveness of an area. To the extent that wetland area has been reduced, and therefore its capacity to buffer fluctuations, the result will be more severe consequences of fluctuations, which will also make the area less attractive.

From the standpoint of fluctuations, the ability of natural ecosystems such as wetlands to absorb those fluctuations is of the greatest significance. As mentioned earlier, wetlands depend on fluctuations for their existence and provide an attractive, productive buffer zone that allows fluctuations to occur without necessarily producing adverse consequences. Measures that are overly stringent in controlling fluctuations will reduce wetland area and its inherent buffering capacity. Adverse consequences of measures can also reduce or eliminate this natural buffering capacity and increase the vulnerability of human activities as a result.

5.3 <u>Feedback Effects that Can Reduce the Capacity of Natural Ecosystems to Absorb Fluctuations</u>

Finding the feedback loops in the relationships among natural ecosystems, human activities, and hydrological fluctuations can help us identify some important areas for analysis and action, as well as a critical trap to avoid.

There are several loops in the set shown in Figure 13 that bring the system into equilibrium if adverse impacts on natural ecosystems become extreme. These loops, through impacts of development, recreation, water quality and availability, capacity for buffering fluctuations, and esthetic effects all affect the attractiveness of areas in the basin and eventually, slow growth. However, significant time delays in these loops, before the problems are recognized and action is taken, may allow adverse impacts to degrade substantially the environment. Since these loops are acting as "brakes" against the acceleration created by positive loops from development, the delays may allow development to become insupportably dense.

Anything that reduces the time delays in these loops will have beneficial effects for the natural ecosystems and the human activities that depend on them. More careful monitoring of the effects of development on ecosystems, for example, will "sound the alarm" sooner and prevent development from becoming excessive. Regulations protecting the most sensitive ecosystems can also help. Although such measures do not appear as if they have a direct relationship to the problems of fluctuations, they do when viewed in the context of the larger system. Measures that protect natural ecosystems and their inherent buffering capacity help to reduce the consequences of fluctuations. By resisting excessive development, these measures can also help to reduce vulnerability, the other major contributor to consequences of fluctuations.

The trap to be avoided resides in a set of positive loops that wound their way through the relationships in Figure 13. These are highlighted in Figure 14. Measures to reduce fluctuations and their consequences may produce vicious circles leading to ever greater dependence on measures if they reduce the capacity of natural ecosystems to buffer fluctuations. This may occur directly as a result of limiting fluctuations or as an adverse byproduct of various measures. In either case, consequences will lead to greater pressure for measures. The way to break these vicious circles is to select measures that are compatible with the protective functions already offered by natural ecosystems. Protective structures should only be used where there are not natural "structures" such as beaches available. Structural measures clearly have a role, but should be used carefully in a way that complements rather than works against nature.

A comprehensive strategy for dealing with fluctuations should emphasize use of natural ecosystems' capacities for minimizing the consequences of fluctuations and protect natural ecosystems as needed manmade structures are developed.

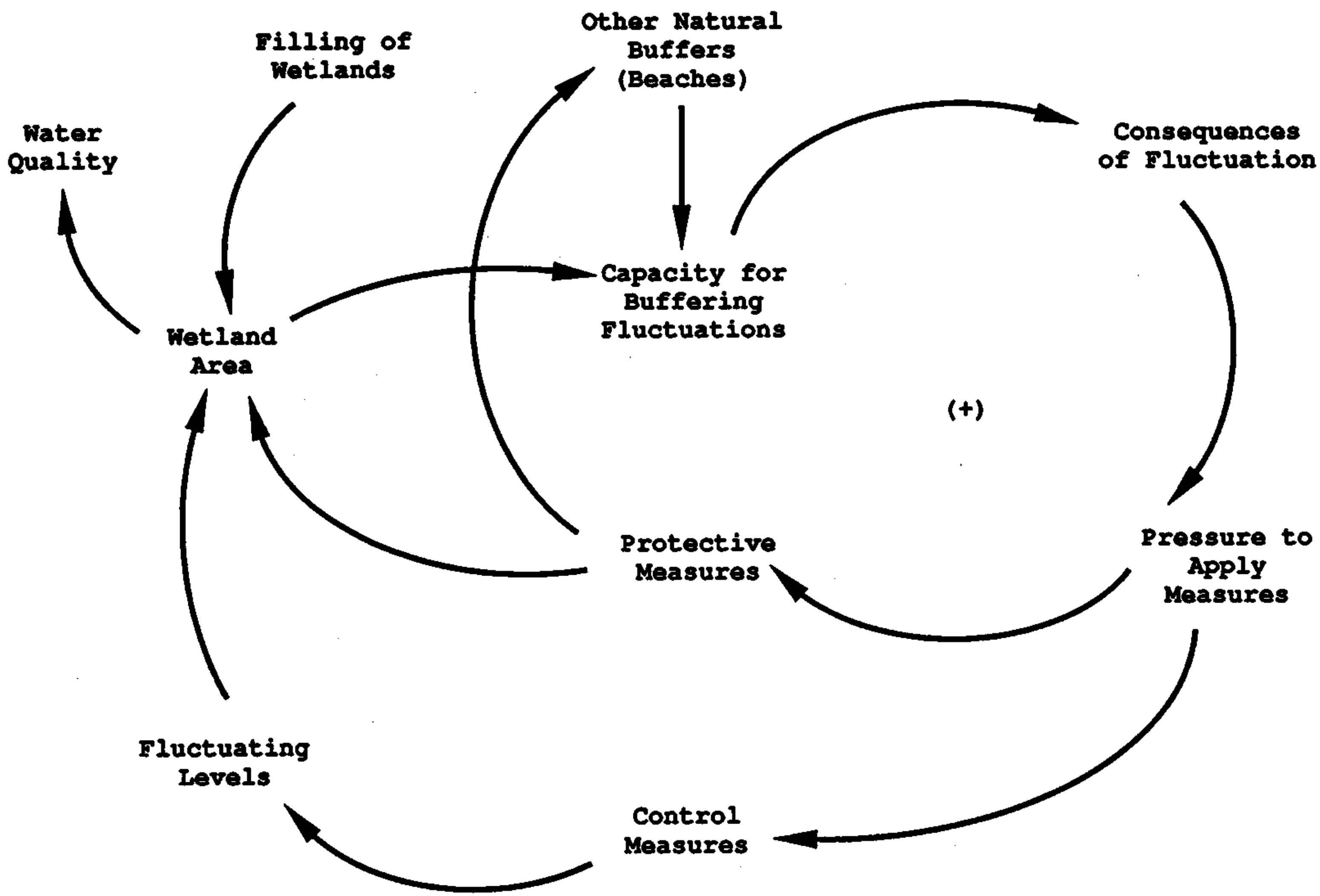

Figure 14: Reduction in fluctuations may have the adverse effect of reducing wetland area and therefore the capacity of wetlands to buffer the effects of fluctuations that do occur.

GOVERNANCE

6.1 Introduction

The governance structure that was alluded to earlier refers to the amorphous decision-making processes about water levels and their consequences. It does not comprise a well-coordinated, set of activities, but consists of a patchwork of Federal, state, provincial, and local bodies and agencies operating under the laws of two different countries. Just as the interests using the lakes are a diverse group, these agencies have somettimes differing objectives and relationships to the lakes and the consequences of fluctuations. Some agencies focus primarily on the lakes while most others have the lakes as only one of a number of other concerns.

The governance structure interacts with the lakes and consequences of their fluctuations in three principal ways:

- <u>Land use regulation and planning of public facilities</u>: These functions affect the concentrations of interests in various parts of the basin as well as the public facilities that are built. These activities, in turn, affect vulnerability to fluctuations.

- <u>Planning, implementation, and administration of measures</u>: These include control structures and their operating plans, protective structures and other measures, mitigation of damages caused by fluctuations, and helping interests to adapt to fluctuations.

- <u>Advisory and advocacy functions</u>: These influence perceptions of the role of government regarding fluctuations and measures designed to deal with them.

6.2 Land Use Regulation and Public Facilities

Figure 15 shows how the governance structure affects regional development and the concentration of interests in the basin, and thus, vulnerability to fluctuations. As interests become more concentrated in an area, the intensity of development has impacts on humans, as well as on the natural ecosystem. The severity of the impacts will depend on an area's capacity for development, as well as the intensity with which various interests use the lakes and their shores. The impacts may provoke a variety of responses from the governance structure, including new land use regulations and more stringent enforcement of existing ones. At the same time, the governance structure can also make investments in infrastructure that increase an area's capacity for development by reducing the adverse environmental impact of development.

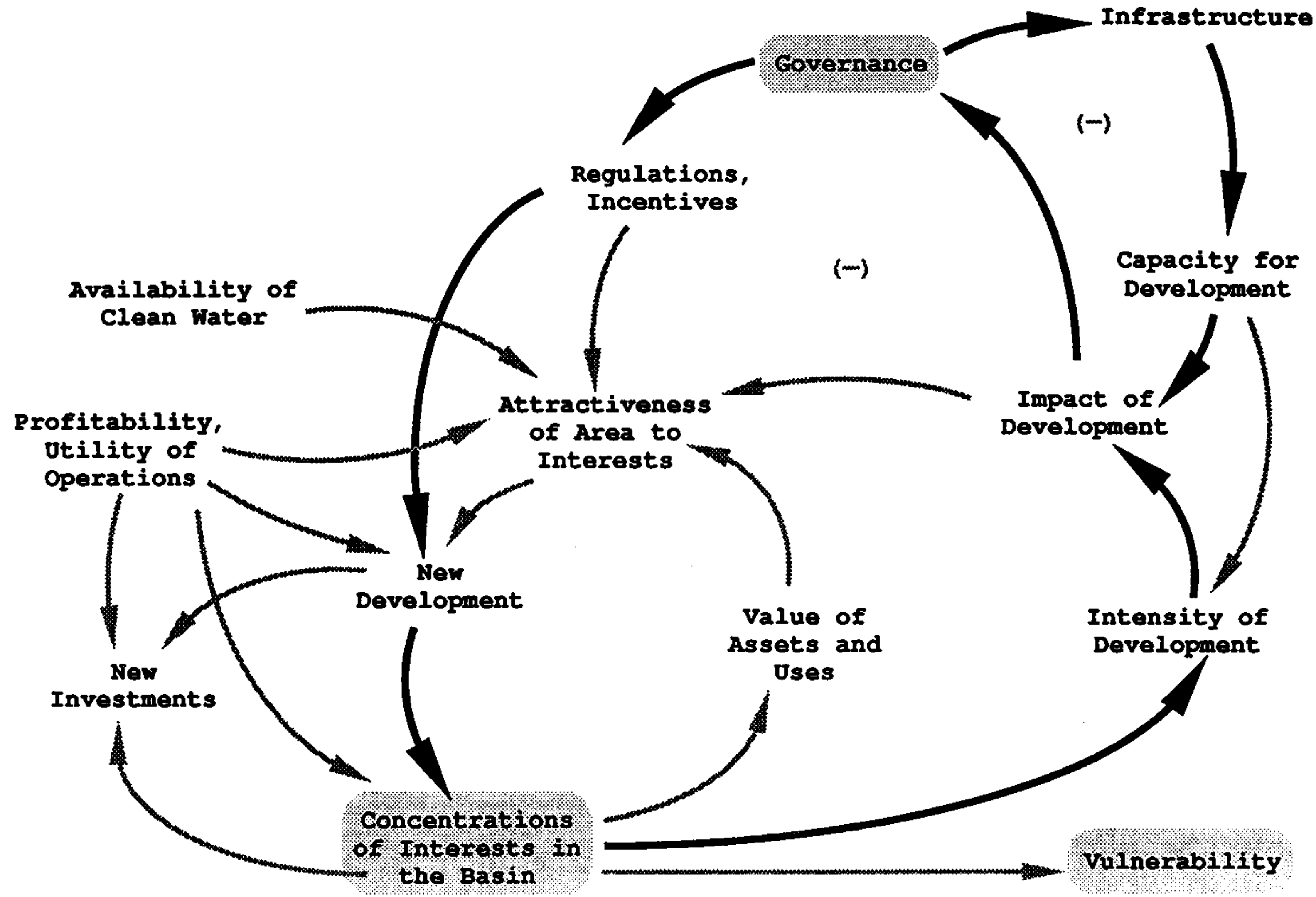

Figure 15: One effect of governance on vulnerability is through its effect on the pattern of development in the basin and activities of interests along the shoreline. By developing infrastructure, governing agencies may also contribute to greater concentrations on the shoreline.

Governance processes introduce two additional feedback loops into the dynamic process by which concentrations of interests grow, as was shown in Figure 11. The loop through regulation resists growth in concentrations of interests when these exceed an area's capacity for development and produce adverse impacts. In another loop, governance reacts to the adverse impacts by adding to the infrastructure, alleviating the impacts, and allowing more growth to take place.

The balance between these two loops, together with the economic forces that promote development, determines the concentrations of various interests in an area at each time and ultimately affects vulnerability. Maintaining the appropriate balance is a key role for governance. Too weak a regulatory response may allow an area to become overdeveloped.

In addition to adverse impacts on humans and on ecosystems, high concentrations of interests may increase vulnerability to fluctuations as well. This increase in vulnerability is more likely if the absence of regulation permits building in areas vulnerable to damage or developing uses that are in themselves particularly vulnerable. An appropriate regulatory response should both influence overall growth and explicitly deal with vulnerability, as controlling overall growth alone can help (by reducing the concentration of interests), but can still allow significant vulnerability to develop.

Building infrastructure has a positive effect on reducing adverse impacts, but contains a potential trap. The increased development made possible by infrastructure can add significantly to vulnerability, unless accompanied by an awareness of the extent of fluctuation that can occur within the structures' lifetimes. This does not argue against development or infrastructure that enables development to expand. It does indicate the need for coordinated governance responses that match development to capacity and assure that development avoids areas and uses that are vulnerable. This coordinated response is often difficult to achieve because of the often time independent nature of the processes involved, although in some areas, regional planning commissions have been successful in helping to achieve the needed coordination and appropriate responses to land use and environmental problems.

6.3 <u>Measures</u>

Measures promulgated by the governance structure to deal explicitly with fluctuations and their consequences can have several types of effects. As shown earlier in Figure 7, control measures affect fluctuations directly while protective measures reduce vulnerability. Mitigation measures lessen the consequences of fluctuations by reducing the costs to interests.

Adaptive measures reduce vulnerability by promoting the consideration of fluctuations in making investment and design decisions. Measures are not neutral, however. Some measures, because of the loops that exist in the system being described, can produce the following effects:

- Opposition that keeps measures from being implemented.
- Unintended consequences that produce additional problems or increased vulnerability.

6.4 Opposition to Measures

Some feedback loops in the system generate opposition to particular measures. Figure 16, for example, displays a set of loops that can produce opposition to control measures.

Control measures are appealing because they have their effect without causing individual interests to incur costs, either directly or indirectly. Because measures usually have their effects over entire lakes, it is difficult to charge the costs to the interests that benefit. However, because control measures have their effects over entire lakes and affect a broad range of interests, proposals for specific measures that meet some interests' needs could create opposition from those with different needs.

Adverse effects of control measures will produce additional opposition. The often significant costs of such measures will also cause taxpayers with no direct stake in the lakes to question the value of these expenditures. Thus it might become difficult to muster the political consensus necessary for implementation.

Control measures are not the only kind of measure to generate their own opposition. Adaptive measures can provoke opposition because they cause interests to bear costs that are more certain and immediate to them than the intangible costs of vulnerability. An adaptive measure such as land use regulation reduces vulnerability over time, but also reduces the availability of buildable land. In an area of rapid development, this limitation drives up the prices of the remaining parcels. These higher prices, as shown in Figure 17, make people less receptive to land use regulation because they are giving up more by not building on properties with restrictions. People who can build, but are still subject to some restrictions, also incur an opportunity cost. If development has already been intense, the opportunity cost will be even greater as there will be less flexibility to build while complying with land use regulations.

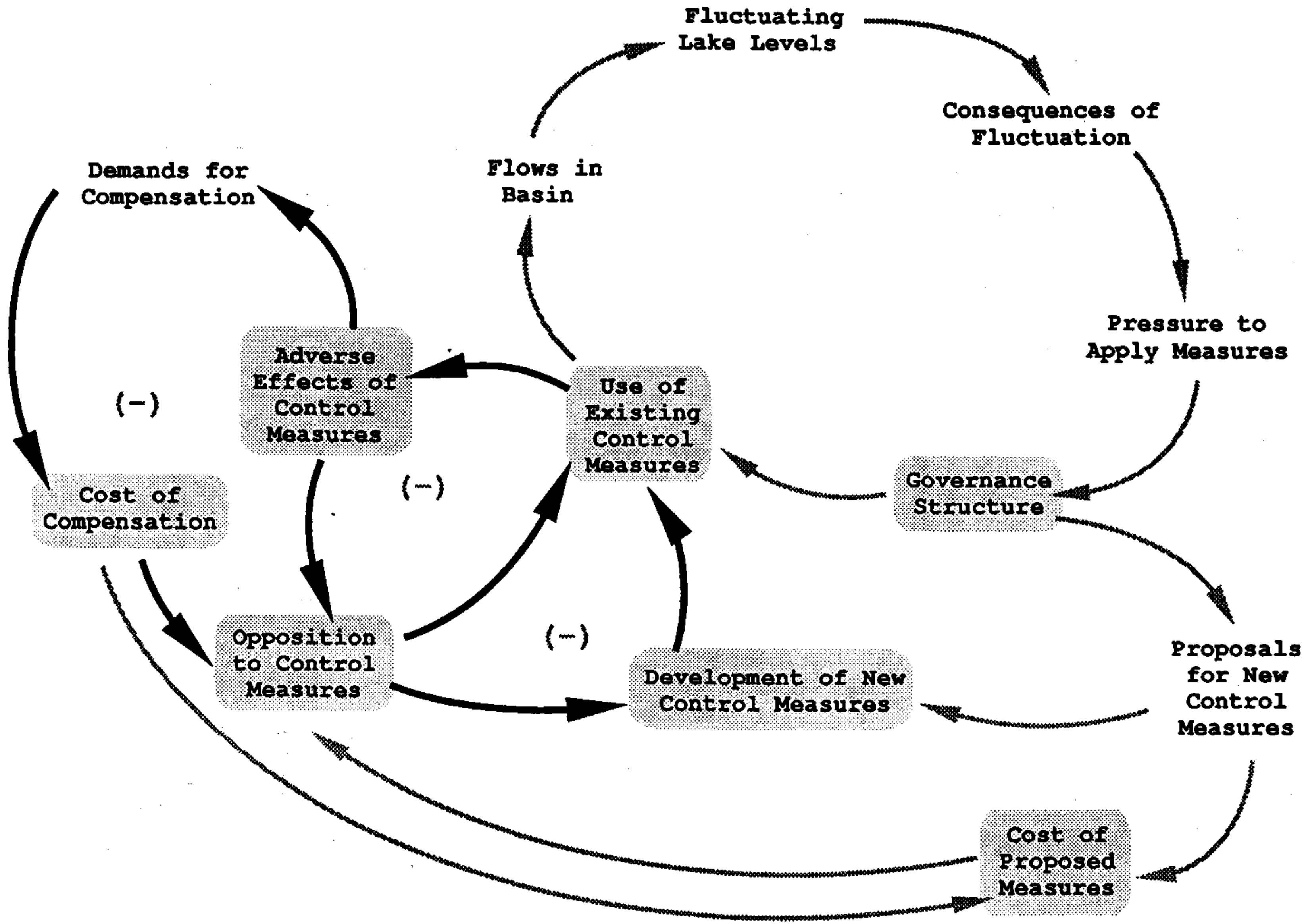

Figure 16: Resistance to control measures can develop as a result of their cost, potential adverse effects, and cost of compensation to mitigate adverse effects.

The result of the resistance that could be thus generated may be a relaxation of the restrictions or lax enforcement of existing regulations. Because of the possibility of opposition undermining regulation, it is important that regulations have some "teeth" and that they are rigorously enforced.

The implications of this opposition for designing and implementing measures are:

- Implementation of measures needs to be carefully thought through. It cannot be simply taken for granted.
- As indicated elsewhere, balanced sets of measures are essential. Relying too heavily on a single type may produce minimal results if opposition limits that which can actually be done.
- Opposition to measures can increase conflict. If, however, governments understand the sources of opposition, they can play an effective role in mediating conflict and moving toward effective solutions.
- Understanding opposition arising from adverse effects can help policymakers design compensatory actions that reduce conflict and aid implementation.

6.5 Unintended Consequences of Measures

Measures also have the potential for creating unintended consequences. These unintended, often adverse, consequences can result from what appear to be reasonable actions. An example can be found in mitigation measures, such as payment of flood insurance claims for storm damage. As shown in Figure 18, a loop through damages produces pressure on the governance structure, which, in turn, responds with payments. The payments reduce the net cost of the damage in a way that affects the balance between perceived potential damage and opportunity cost in an individual's decision making. This shift leads to greater vulnerability and more damage. The loop through damages, design range, and vulnerability should reduce vulnerability, but is weakened by the effect of mitigation measures in reducing net cost to those affected. The result is additional growth in potential vulnerability.

The manner in which flood insurance is administered can help reduce the effect of such a possible trap. Communities joining the program should meet certain standards for land use regulation in designated flood plains. However, owners of existing structures obtain flood insurance at a subsidized rate and can rebuild their structures after suffering damage. The subsidy

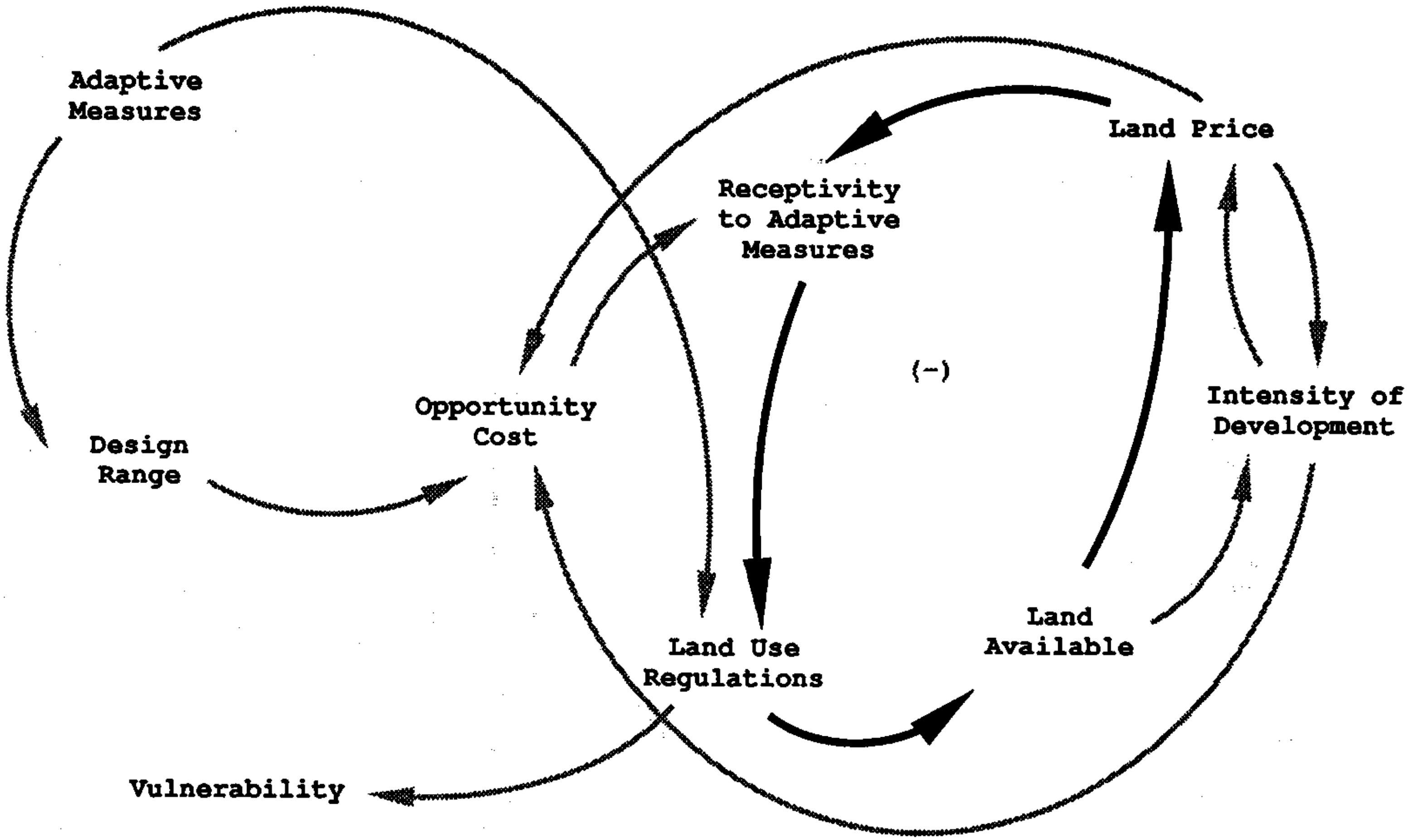

Figure 17: Land use regulation, one of the principal adaptive measures, can reduce the building land available, drive up its price, and reduce receptivity to further regulation because of the opportunity cost it would entail.

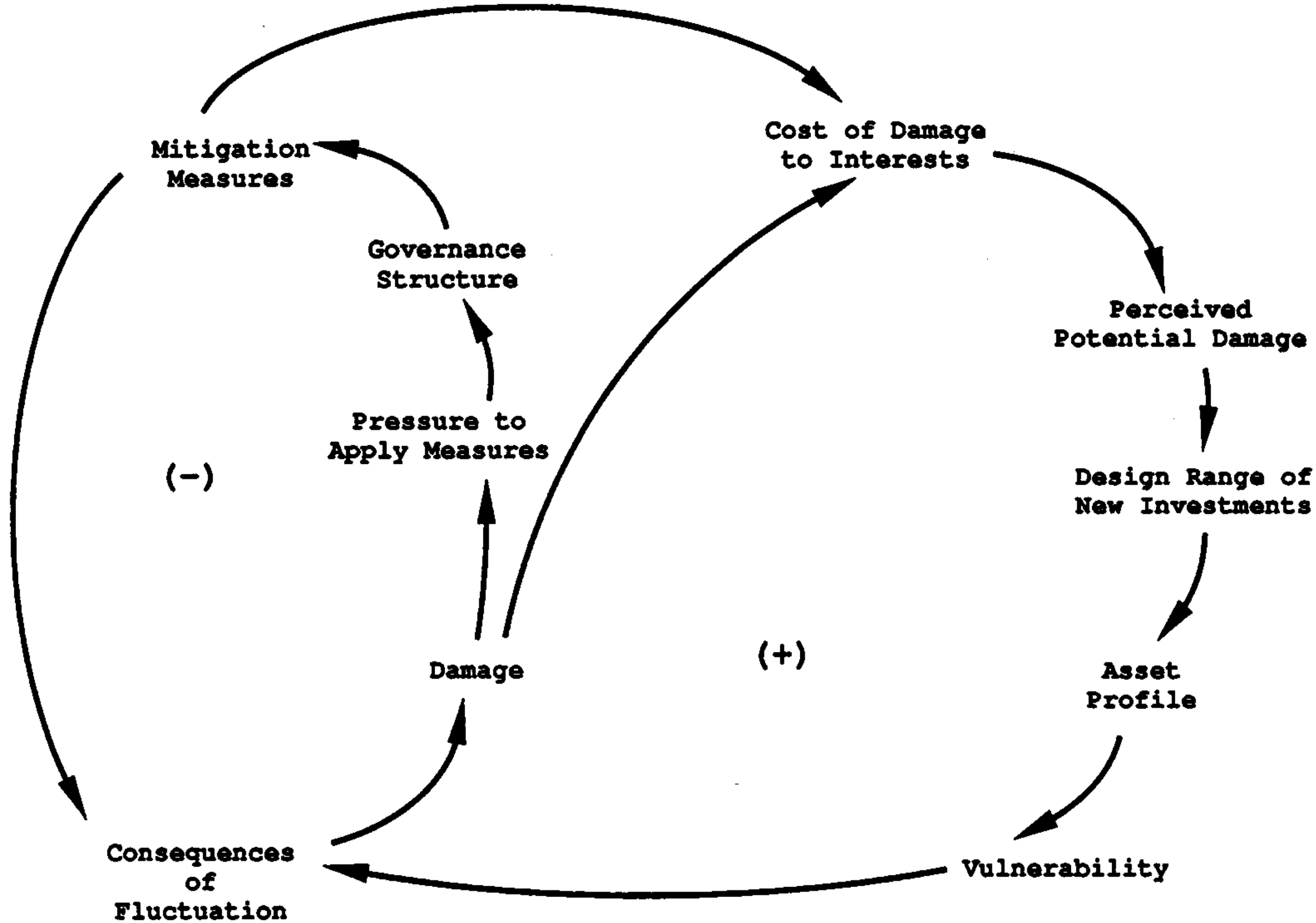

Figure 18: Mitigation measures may inadvertantly increase vulnerability by reducing the actual cost of damage to interests as well as reducing the perceptions of potential damage.

built into flood insurance pricing creates an incentive that increases vulnerability through the loops shown in Figure 18. More realistic pricing of flood insurance would provide owners with better information on risks and could be used as an incentive to promote less vulnerable investment and design. Other incentives might be used to get owners who suffer damage to rebuild in safer places.

Another type of trap, alluded to earlier, can arise from the use of control and protective measures. These types of measures can reduce consequences, but they can also have unintended effects in increasing vulnerability. As shown in Figure 19, consequences of fluctuations lead to pressure on governance that can result in measures that either reduce the range of fluctuations or vulnerability of structures on the shoreline. However, there is also a loop that can cause vulnerability to grow by reducing perceived damage and the importance of a sufficiently large design range. By reducing the incidence of damage from minor storms and increasing the interval between episodes of major damage, these structures also allow more development to occur in vulnerable areas.

There are also additional loops that add to the trap inherent in using protective structures. These structures themselves are subject to damage and can add meaningfully to an area's vulnerability to a serious storm. Damage to these structures, as well as the properties they protect, will increase the pressure to develop more protective structures and add to vulnerability in a vicious circle that may make an area more dependent on protective structures than can be justified by the efficacy of those structures. On the other hand, costs of repairing and maintaining protective structures, adverse effects of those structures, and poor performance relative to expectations may dissuade people from using protective structures in inappropriate situations. Unfortunately, the knowledge base that would help prevent inappropriate uses of protective structures is often unavailable or not used.

What are the policy implications of these unintended consequences? Again, the existence of such potential consequences is not an argument against using these types of measures. They do, however, indicate a need for a careful approach to the design of measures and the use of the appropriate combinations of measures in such a way that they mutually reinforce a desired outcome and yield a balanced and cost- beneficial result.

Protective structures, for example, would be the appropriate choice where there is already high density development. They may be essential in order to protect sites such as Lakeshore Drive in Chicago, where significant investment is already in

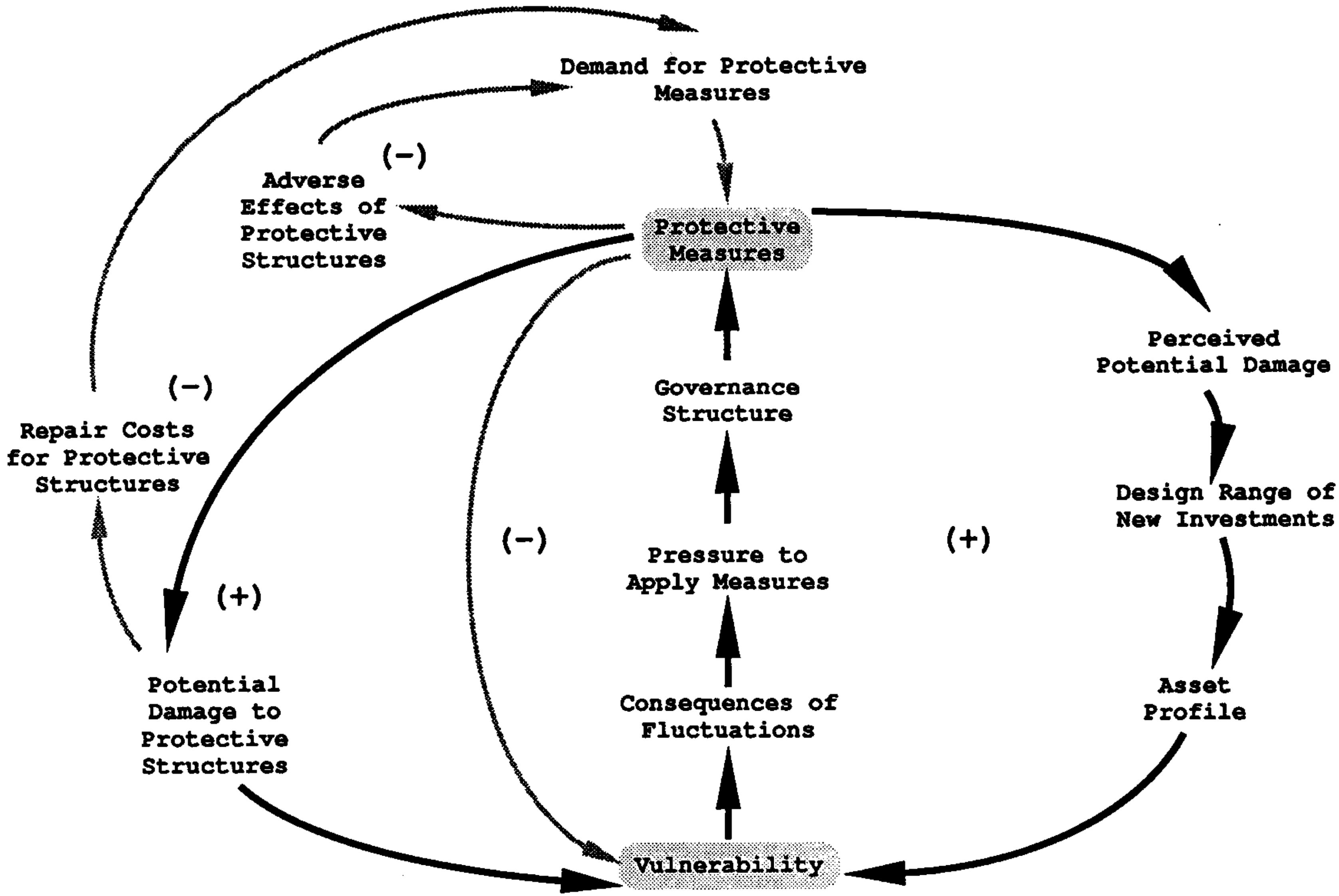

Figure 19: Protective measures can contribute to increased vulnerability by reducing perceived potential damage and by putting additional (protective) structures in the way of possible damage. Adverse effects of protective structures and costs of maintaining them may dampen demand for those structures.

place. They may not offer the best approach when used for protecting beach cottages that can be moved from the shore for less expense than building the protective structure. Public programs should also provide incentives for selecting protective measures that are most effective for achieving desired results. Better information provided by such programs can help strengthen the loops that work against inappropriate uses of protective structures.

Coordinating land use planning and regulation with programs to build protective structures is especially important because it can help to avoid the effects of the loop through protective structures, perceived potential damage, and vulnerability. This coordination would make it more difficult to build in vulnerable areas. Assistance with protective structures that are appropriate might be used as an incentive to encourage participation in land use planning and regulation and make that adaptive measure more palatable.

6.6 The Expanded Role of Governance

The various issues involved in the development of effective policies suggest a broader role for governance than merely responding with measures. As discussed earlier, governance processes should help people better understand the problem of fluctuations. Without the broader perspective that a well-designed educational effort can provide, individuals are likely to see the problem narrowly in terms of how it affects them. While this is understandable, it allows individual interests to fall into the kinds of traps described above and resist attempts to deal effectively with the problem. As was suggested earlier in Figure 12, educational efforts can help shift the perceptions of interests and enhance the public's understanding. This can help interests make more appropriate investment and design decisions while also being more receptive to the comprehensive set of measures needed to deal with the problem.

The governance system can, in fact, play a number of constructive roles in accelerating this shift in mindset and in the environment that would follow. As shown in Figure 20, education is a critical function that governance could perform. Governance could also serve as a catalyst for joint planning. This would enable interests to play an active role in implementing concepts of adaptability and increase their commitment to the solutions that emerge. A similar process has been used in the area of water quality. Another function of joint planning would be to allocate the "development capacity" of areas and to find ways of "stretching" capacity through infrastructure investments while limiting vulnerability.

Another role of governance would be one of facilitating self-organization, stimulating effective actions, and increasing cohesion among the levels of government and the many different agencies involved. This function would be necessary for a coherent, comprehensive response, as elements of the problems are so diverse and come under the jurisdiction of disparate set of agencies. There are a number of different points in the system where governance can have a constructive effect, but to be effective the response of the various agencies must be coordi ated.

Governance can also play a role in mediating conflict and channelling the disparate initiatives and responses into mutually supportive approaches to problems. It is therefore important to understand the causes of conflict produced by interests' responses to fluctuations and by opposition to measures.

Measures cannot ultimately be effective in dealing with fluctuations unless they are produced by a governance process that is equipped to deal with all the various aspects of the problem. A governance process that merely responds to pressures cannot undertake a proactive approach in reducing vulnerability. An effective process should organize the various levels of government and agencies involved to support a proactive approach to reducing vulnerability, as well as responding effectively to consequences after the fact. Thus any set of measures should include enhancements to governance structures and processes necessary to make those measures work.

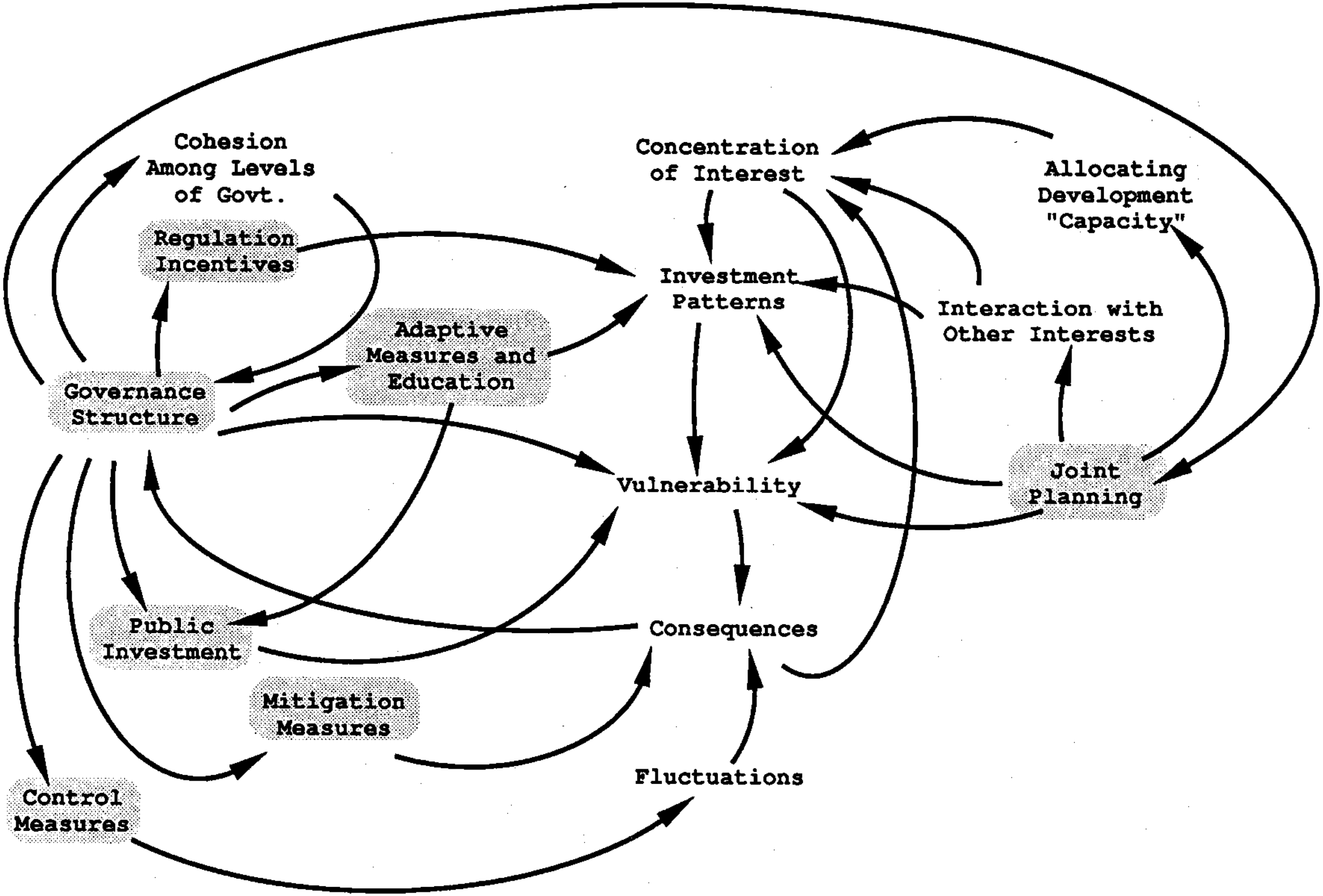

Figure 20: Governance can have an effect on the consequences of fluctuations in many different ways. An expanded role for governance will include the kinds of measures discussed earlier as well as regulation of and incentives provided to interests. It may also include programs that effect patterns of public investment and their contribution to vulnerability, joint planning in critical areas such as land use and crisis management, public information programs and efforts to achieve coordination amoung the different agencies involved.

SUMMARY AND CONCLUSIONS

7.1 A More Detailed Overview

The preceding Sections have described each of the components of the system in some detail. Before leaving the discussion of the systems context to explore its implications for policy, it is worth taking a moment to summarize how these components fit together. This return look at the overall system will then be used as a basis for some conclusions about the requirements for an effective response to the consequences of fluctuations.

Figure 1 provided an overview of the context pertaining to the problem of water level fluctuations and its consequences. Figures 21 and 22 add some of the details that have been elaborated in the intervening Sections and places them in the context of the overall system.

Of key importance, as shown in Figures 21 and 22, is the central role that vulnerability plays in determining the consequences of fluctuations. Vulnerability is principally a function of concentrations of interests in the region and the results of investment decisions made over time by those interests as reflected in their asset profiles. Investment decisions cause only gradual shifts in the asset profile. The design range incorporated in new investments will cause gradualshifts in vulnerability, increasing or decreasing it depending on the importance that interests place on having a large enough design range relative to other considerations such as economic efficiency. The range of fluctuations accommodated by the design of investments balances perceived potential damage and the opportunity cost of sacrificing utility and profitability by having a larger design range. Perceived potential damage depends on having accurate information on past damage, likely trends in levels, and adequate incentives to act on that information.

Fluctuations themselves are still, of course, an important factor. Fluctuations in static levels and storm effects have different impacts. Storm effects usually have the more serious consequences, although very high or low static levels can also have subtle, but far-ranging impacts.

The natural ecosystem depends on fluctuations for its integrity and healthy functioning and, in turn, has a number of critical effects on human activities including the maintaining of water quality and acting as a buffer to the consequences of fluctuations.

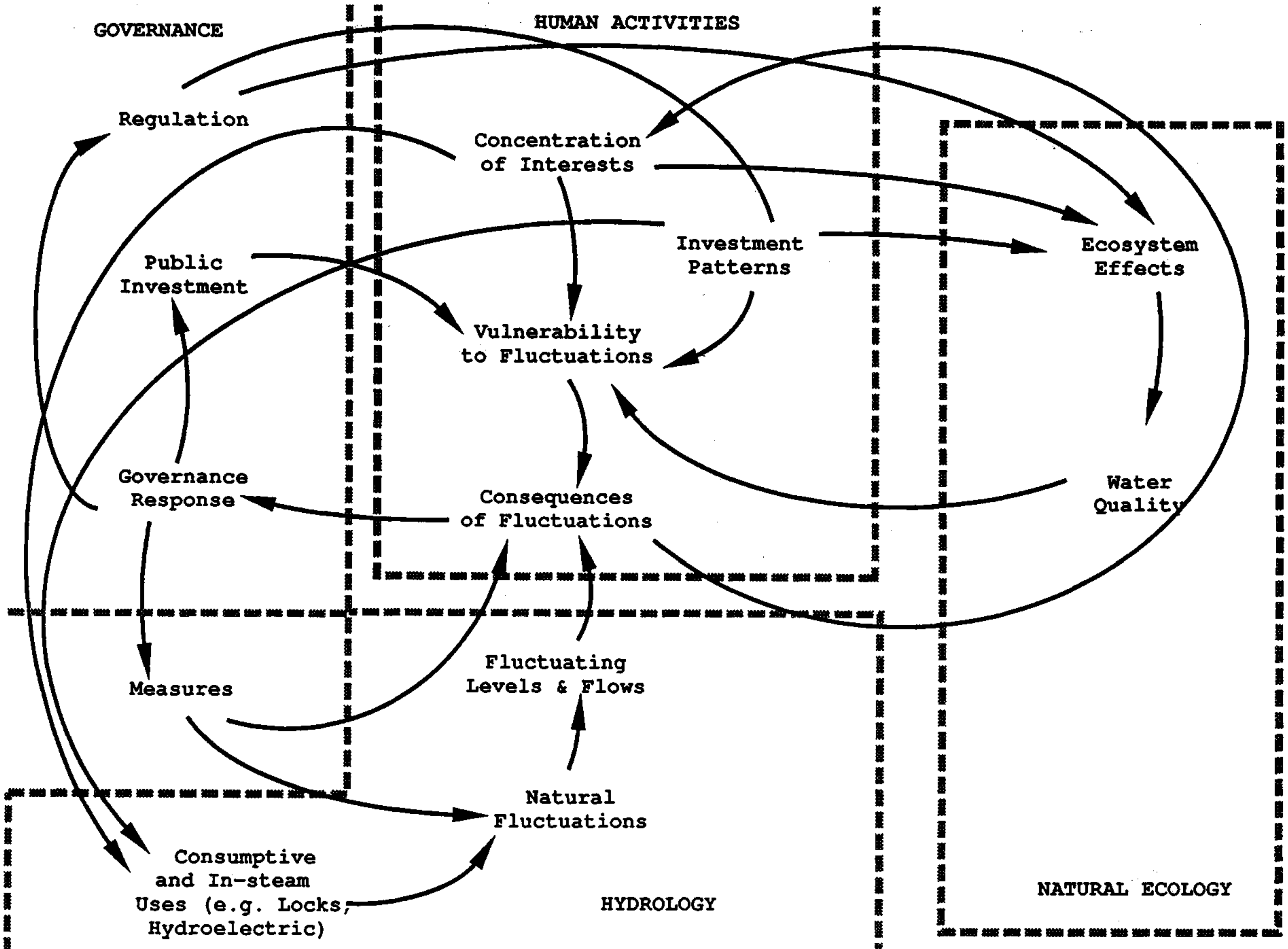

Figure 21: Summary overview showing key elements and interactions with emphasis on the concept of vulnerability.

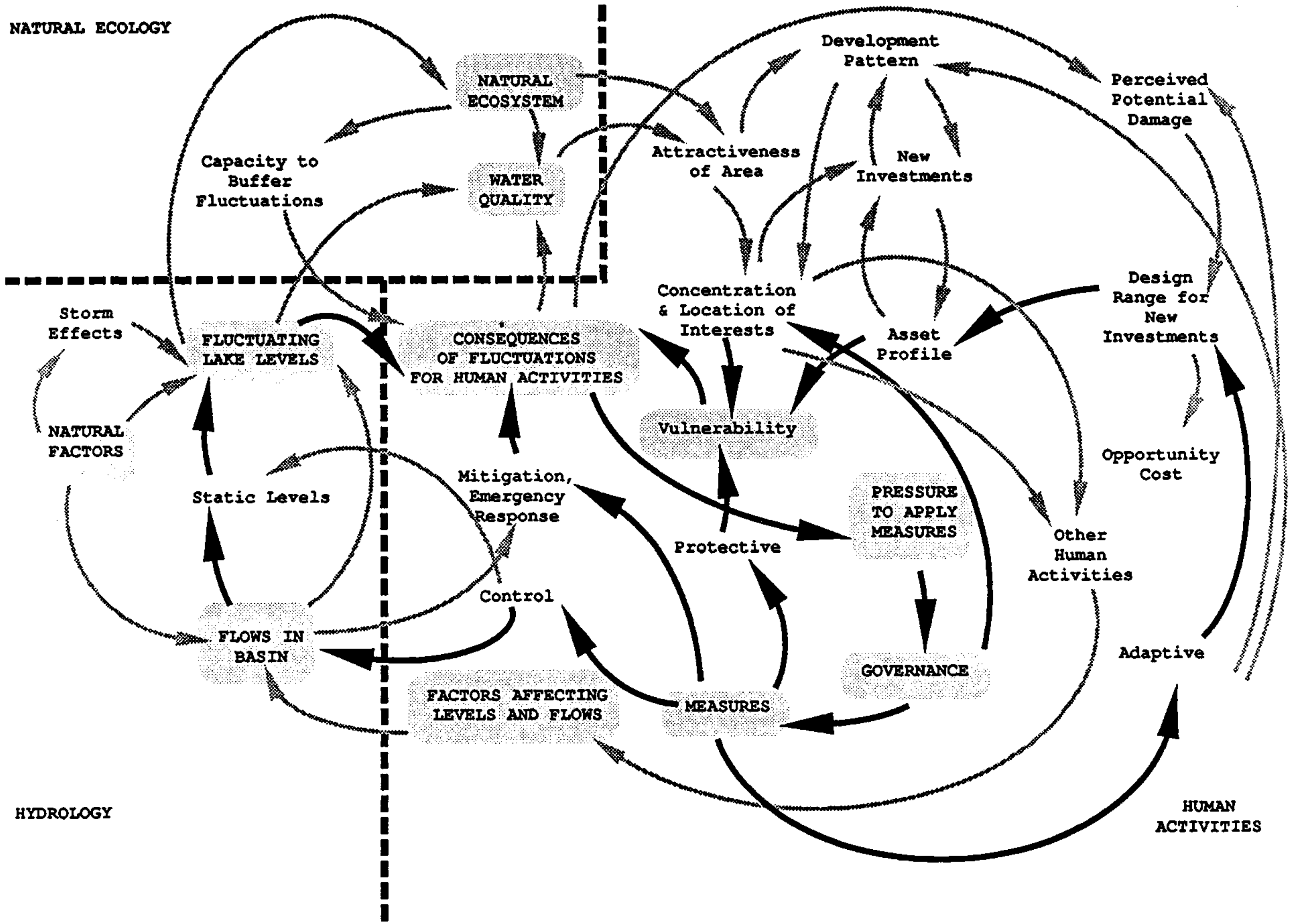

Figure 22: Detailed system overview emphasizing the central role of the concept of vulnerability, enlarging on key variables which influence it.

Governance has its impact on consequences of fluctuations through measures that have different types of effects: Direct control of fluctuations (in static levels), reduction of vulnerability through protective structures, mitigation and emergency responses to consequences, and reduction of vulnerability through incentives and information that promote more adaptive designs. Governance also indirectly affects vulnerability and consequences of fluctuations through its interaction with the development process and resulting impact on the concentrations of various interests.

The more detailed overview shown in Figures 21 and 22 indicates the critical importance of managing vulnerability as part of a broader-based strategy for dealing with the consequences of fluctuations. The feedback loops through vulnerability and other aspects of human activities require a dynamic approach. This approach should reinforce the perception of potential risk due to fluctuations and, at the same time, provide interests with assistance and incentives for acting to reduce their vulnerability.

7.2 Conclusions Drawn from the Context

7.2.1 Overview

o Hydrological fluctuations and their consequences, human activities, and the natural ecosystem form a seamless web of interrelationships. Problems caused by fluctuations cannot be dealt with effectively by manipulating one part or a limited number of parts of this system above.

It is the nature of complex systems that narrowly-focused solutions can create their own, sometimes unintended problems and can thus prove uneffective. Broad-based approaches that address the many facets of the problems are essential.

o The nature of this complex system affecting the consequences of fluctuations requires that all relevant aspects of the problem be examined in the course of crafting solutions. These aspects include flows as well as levels, consequences of low flows and levels as well as high ones, and effects on water quality. Complexity should not be seen as a barrier to understanding and acting on the problem of fluctuations, but rather as a watchword for thoughtful analysis.

7.2.2 Hydrology

o Fluctuations of lake levels and flows of water within the Great Lakes Basin are an inevitable consequence of varying amounts of rainfall between seasons and from year to year. Fluctuations are a necessary corollary to the benefits of storage (e.g., a steady source of water despite variability in precipitation) that the lakes provide. Uncertainty created by the prospect of long-term climatic change makes the benefits of storage even more important, but also introduces the possibility of greater variability in levels and flows.

o Fluctuations cannot be eliminated; they can only be displaced from one place to another. Reducing fluctuations in lake levels will create greater variability for flows in connecting channels and in the St. Lawrence. Reducing fluctuations on one lake will increase the variability of the others' levels. Since the basin is heavily populated, limiting fluctuations for the benefit of one group is likely to affect other groups, sometimes adversely.

o The greatest impact of fluctuations is from storms and related phenomena. Even if fluctuations in static levels can be managed to some degree, storms will continue to occur and be responsible for the most severe damage. Without better data on the relationship between static levels and storm damage than exists now, it is difficult to estimate the benefit from more extensive attempts to control fluctuations in static levels.

o Structures capable of significantly reducing fluctuations in static levels will have to move large amounts of water and will, therefore, be quite expensive to construct. They may also require costly compensation for interests that are adversely affected by the structures' construction and operation. The combination of high cost, uncertainty about fluctuations, and potential conflict generated by control measures makes it desirable to search for other measures that achieve the objectives of reduced damage in a relatively more cost-effective manner.

- There is a place for control measures, despite the above limitations, as part of a comprehensive strategy for dealing with the consequences of fluctuations. The limitations outlined above keep control measures from offering an effective solution by themselves and require that they be used in concert with a well-designed combination of other types of measures.

7.2.3 Human Activities

- Human activities related to the Great Lakes are diverse in nature and have different needs relative to desirable levels and flows. Even within what nominally appear to be homogenous interest groups, there is a great deal of variation caused by differences in local situations. This diversity requires that strategies for dealing with fluctuations also be multifaceted and capable of being applied flexibly in different situations.

- Human activities can affect fluctuations, both directly through measures and as a by-product of other activities, and, in turn, have some impact on the consequences of fluctuations for human activities themselves. However, the most profound effect of human activities on the consequences of fluctuations is the result of their tendency to create vulnerability. People do not set out to create vulnerability, but may inadvertently make investments that are vulnerable because they lack information about risks or because they feel the cost of designing to avoid harm from fluctuations is too great.

- Measures designed to deal with consequences of fluctuations must include measures that affect human behavior in ways that help to reduce vulnerability. Providing better information is important but incentives that cause individuals to design and build facilities that are better adapted to fluctuations are also necessary. Incentives that cause people to reduce vulnerability may prove to be a very efficient way of lessening the future consequences of fluctuations compared to protecting investments that are built in vulnerable areas after the fact.

- Vulnerability is a consequence of patterns of development. The way in which development is done in proximity to the lakes -- its density, elevation, location, design -- will contribute to increasing or decreasing vulnerability. These aspects of vulnerability are a product of human activities (compared to fluctuations themselves, which are natural phenomena), are more readily subject to control, and, therefore, merit special attention when creating comprehensive strategies.

7.2.4 Natural Ecosystems

- Human well-being depends on the health and integrity of natural ecosystems. These ecosystems require fluctuations to maintain their richness and diversity. Efforts to reduce the consequences of fluctuations for humans should not adversely affect natural ecosystems, either by keeping the range of fluctuations too small or through negative impacts of particular measures.

- Natural ecosystems themselves help to buffer the effects of fluctuations. Measures that reduce the natural capacity to buffer fluctuations may create increasing dependence on man-made measures. Relying on man-made structures is wasteful when natural features can achieve the same result. When man-made structures are required, they should be constructed in a manner that enhances rather than detracts from the beneficial functions of natural features.

7.2.5 Governance

- Consequences of fluctuations require a well-coordinated response from the governance processes that relate to the Great Lakes. Yet, a coherent strategy is difficult to implement because various aspects of the problem are the responsibilities of international agencies, numerous public agencies in two different countries at Federal, state or provincial, and local levels, quasi-public agencies, and advocacy groups representing particular socio-economic interests. A coherent governance response requires a consistent set of principles that guides the actions of these agencies and groups toward common objectives while allowing them maximum flexibility in adjusting for local conditions and needs. A much higher degree of coordination than now exists is also needed to achieve a coherent response.

- Governance processes should assure a balanced approach and select measures that, taken together, deal with the multiple facets of fluctuations and their consequences. Measures to control and protect against fluctuations, mitigate damages caused by fluctuations, and get people to adapt better to fluctuations should be combined in a manner that reduces consequences in the least costly way. The ultimate focus of governance should be on reducing vulnerability. Governance functions not directly focused on issues of fluctuations (e.g., land use planning, building infrastructure) should also be carried out in a manner that helps to reduce vulnerability and keep it from increasing in the future.

- The role of governance should go beyond promulgating measures. Governance processes should provide a forum for discussion, conflict resolution, and decision-making in dealing with the consequences of fluctuations. Governance can facilitate these activities by generating and disseminating the requisite knowledge and information and serving as a catalyst for planning and implementation of measures that emerge. Effective governance processes can assist in bringing about a shift in mindset for all participants, from apperceiving the problem solely as a "natural disaster" to one that relates to the nature of human activities and could, therefore, be successfully addressed and controlled.

Following all these considerations, the next section of our report (Appendix D-3) will discuss the broad implications of the systems context for policymaking and management.

APPENDIX D-3

THE GREAT LAKES: ECOSYSTEM PERSPECTIVE--IMPLICATIONS FOR WATER LEVELS MANAGEMENT

II. IMPLICATIONS FOR POLICY AND MANAGEMENT

Functional Group 5

June 14, 1989

THIS REPORT HIGHLIGHTS SOME OF THE GENERAL IMPLICATIONS OF TAKING A WHOLE-SYSTEM VIEW OF LEVELS ISSUES. IT FOCUSES ON: "IMPLICATIONS OF THE SYSTEM PERSPECTIVE", "THE NEED FOR AGREEMENT", "THE NEED FOR AN OVERALL STRATEGY", AND "THE NEED FOR EFFECTIVE GOVERNANCE". IT IS MEANT TO PROVIDE GENERAL GUIDANCE IN FORMULATING POLICY RATHER THAN TO SERVE AS A SET OF RECOMMENDATIONS FOR SPECIFIC ACTION.

II. IMPLICATIONS FOR POLICY AND MANAGEMENT

APPENDIX D-3

TABLE OF CONTENTS

IMPLICATIONS OF THE SYSTEM PERSPECTIVE

Taking a whole system view and an ecosystem perspective has many important practical implications to policy development and to the emergence of an appropriate approach for the management of fluctuating lakes levels and their consequences.

- Water-level related issues cannot be approached as a single simple problem. Instead they present themselves as a cluster of problems, different but interrelated. In particular:

  - Levels issues are ultimately inseparable from water quality issues, especially with regard to low flows and levels in tributaries and subbasins.

  - Efforts to manage lake levels, particularly through large-scale application of structural measures, are bound to have significant effects on the basin's ecosystem.

  - Levels issues are closely tied to shoreline activity and, because of the interface of fluctuating waters and human activities, they are inexorably linked to the region's physical and economic development and the future well-being of its population.

  - Measures ought to be conceived as part of an overall co-ordinative effort integrating water quality issues, economic development plans, ecological considerations, and long-term land-use planning.

- The multifaceted, multidimensional characteristics of level-related issues including, as they do, various hydrological, climatic, environmental, socio-economic, and political aspects, ought to be reflected in the general philosophy underlying an approach to management. Most significantly:

  - Just as level-related issues do not present themselves as one problem, there is no real sense in which a single "solution" exists.

  - Technical and structural means, in particular, will have to be integrated with other efforts in order to be effective over the long run. Piecemeal application of single local measures is not likely to suffice.

- o The complexity of lake level issues is partly derived from the myriad ways in which they impact on human activities:
  - Different interest groups have different patterns of vulnerability to, and preferences for, levels and these sometimes conflict.
  - Even within interest groups, preferences and vulnerabilities are not homogeneous and they may conflict.
  - Perceptions about the nature of problems, needs, and best approaches vary greatly among groups.
  - Agreement about the best course of action is important and is not likely to be easily reached. A special effort may be required for effective resolution.
- o The diverse nature and dynamic characteristics of issues involved with fluctuating water levels require a comprehensive and dynamic response.
  - A flexible, adaptable, high variety approach rather than a monolithic course of action will be required.
  - Emphasis ought to be placed on the concept of managing issues over time rather than on solving "the" problem "once and for all."
  - A continuous, persistent, well structured effort, embodied in a deliberate, well thought out process ought to be, therefore, developed and put in place.
- o All in all, the complex and systemic nature of the problem must be recognized and matched by a sufficiently rich management approach.
  - The emphasis on complexity should not overwhelm action but it should be taken properly into account in crafting appropriate responses.
  - It is important that false expectations are not raised and reinforced by the promise of a single, easy, "quick-fix."
- o The appropriate mixture of measures should be developed to match a variety of needs according to location, extent and type of damage, specific local circumstances, and the like. To be effective, specific measures should be reinforced by other appropriate efforts, for example:

- Protective structures should be combined with land use regulation and other programs that will discourage, where appropriate, overconcentration, and potential increase in vulnerability.

- Regulation and incentive programs should be accompanied by educational efforts that promote awareness, understanding, and compliance.

In general, the underlying systemic nature of water level related issues with the myriad characteristics and affected interests will require a selected set of actions and processes that are accepted, coordinated, and carefully implemented over time. This will call for agreements about objectives, developing a coherent direction for action, and ensuring that there are appropriate mechanisms for governance.

THE NEED FOR AGREEMENT ON PRINCIPLES

Support for, and agreement on, specific courses of action could be greatly facilitated if agreement existed on long term objectives for the region. By defining a shared purpose, agreements on objectives and principles can motivate, guide, and help coordinate efforts. The diversity of interacting interests, jurisdictions, and level-related issues in the Great Lakes basin, make coordinated action especially difficult to achieve but also especially critical. Agreement on underlying principles could be helpful in this respect.

- Broad agreements on objectives and principles could provide a solid foundation for both planning and action.
  - They would provide a framework for co-operation in pursing common goals.
  - They would provide a vision that could galvanize action and steer it toward the attainment of ideals concerning preferred states, as these evolve.
  - They could provide common values and commit to self-imposed constraints, that would define broad parameters within which action could proceed.
- Existing international agreements relating to water quality could be expanded to cover issues related to water levels as well, thus constituting a broad "charter" for the lakes oriented towards the future well being of the basin as a whole.
  - Such a charter could provide guidance for the actions of national governments and local communities alike.
  - It should be based on shared and clearly expressed ethical principles balancing commitment to private ownership, the autonomy and legitimate concern of various interest groups, and the long term need for careful stewardship and preservation and cultivation of natural resources and environmental quality for the common good.
- Agreements will be required on a number of different levels.
  - On one level they could deal with future oriented goals and comprehensive objectives for the region's development.

- On another, they could focus on various procedural questions related to planning, implementation, and relationships between the various governing bodies and between other participants.

o Well crafted agreements could also set a "general tone" and commit to important priorities that, through legislation, could help resolve the conflicting desires of different interests and balance the inevitable pressure of short term needs with the requirements of a more distant future.

Agreements by themselves would not be sufficient, however. Their spirit should be embodied in a definite plan, an overall strategy, specifying a coherent direction for action.

THE NEED FOR AN OVERALL STRATEGY

Because lakes levels issues are multidimensional, dynamic, and interconnected, with links to various other concerns, general management and specific actions are likely to be more effective if they are driven by an overall strategy or a general plan. Specific single actions may be counter productive if taken in absence of such a comprehensive strategy. Providing a coherent concept for action, such a strategy would lay out an agreed upon framework for action, consistent with overall binational regional goals and the specific need to alleviate adverse consequences of fluctuating water levels, ensuring that their negative effects are minimized over time.

- The need for an overall strategy defining a general direction for action is particularly urgent because of the following:
  - The variety and complexity of the tasks involved.
  - The relatively long lead time for planning and implementation.
  - The need to integrate different activities over time.
  - The need for consistency and continuity over time.
  - The need for coherence in concept and action ensuring a concerted effort rather than a sporadic, piecemeal approach.
  - The need for economy in effort and finance.
- Such an overall strategy would be the outcome of a deliberate planning process addressing objectives, direction, and means of action and implementation. The appropriate process for its development should be put in place.
  - Such a process will have to be so designed that it recognizes the need for balancing binational interests.
  - It should also be sensitive to balancing the needs of an overall direction with autonomy of decision-making and actions in specific localities.
- Similarly, an overall strategy ought to reflect the variety of local conditions and needs and make appropriate use of the many different measures that are available.
  - It should provide a flexible guiding concept rather than a rigid master plan.

- It should be general enough to accommodate change and local needs yet specific enough to ensure a coherent direction.

o As a general concept the strategy should lay the overall conceptual tone by establishing, under an overall theme, the appropriate relationship between structural measures and measures aimed at reducing potential vulnerability by regulating various aspects of socio-economic activities.

  - It should thus determine the circumstances under which it is appropriate to focus on fluctuations in water levels, and when to focus on human activity related causes of vulnerability.

  - It should be linked to future development plans for the region.

  - It should address needs that arise due to present arrangements, but be at the same time sensitive to future requirements.

  - It should deal with significant uncertainties, e.g., due to climatic unknowns, by developing robust approaches that do not depend on correctly forcasting levels.

o Although its immediate focus would be on the need to alleviate the adverse effects of fluctuating water levels, an overall strategy would specify how various types of measures and combination of measures ought to be deployed.

  - Depending on local circumstances, topographical conditions, population density, type of damage, and the like, types of measures as components of the overall strategy are likely to include:

    .. Protective measures
    .. Mitigation measures
    .. Adaptive measures
    .. Control measures
    .. Emergency measures

  - Means for addressing the adverse effects of the measures themselves ought to be included.

o Consistent with binational agreement on long-term objectives, as well as with its own general theme, such a strategy would articulate conditions under which various measures and combinations of measures could best be applied, leaving sufficient room for local autonomy in decision and action. As a broad concept, key elements in the strategy are likely to specify the following:

- Introduction of appropriate structural, protective measures where existing densities of population and investment are high.

- Refinement, where appropriate, of existing control capabilities for regulating levels and flows.

- Protection and/or redress of damage to existing, largely individually owned, properties that are vulnerable.

- Introduction of the wide use of adaptive measures such that potential vulnerability related to future development is reduced.

- Institution of effective emergency programs for areas that are particularly sensitive to threatening situations.

o The strategy would also develop approaches to dealing with issues such as the following:

  - Sources of funds and distribution of costs.

  - Priorities, sequencing of implementation efforts, and allocation of resources.

o As a general framework, the availability of a broad strategy would provide, in itself, an excellent template for efforts related to selecting measures. Specific proposals concerning measures and courses of action should be carefully evaluated for their effects as well as effectiveness. They should be screened:

  - First, with respect to consistency with long-term regional goals and with respect to the degree to which they contribute to achieving specific objectives of the overall strategy.

  - Then, with respect to impacts on various important areas of concern, and other criteria, including acceptability, implementability, and the like.

Ultimately, an appropriate governance structure is necessary in order for strong international agreements and commitments to emerge, and for strategies to be defined and implemented. Only effective governance mechanisms can ensure that agreements and courses of actions are legitimate and binding.

THE NEED FOR EFFECTIVE GOVERNANCE

Development of agreements and strategies, and the implementation of specific courses of action, will require a sustained effort, as well as the development of appropriate processes ensuring continuity over time. These should be institutionalized in effective governance mechanisms and institutional arrangements.

- The two most critical functions of governance would be to facilitate co-ordination at all levels and to foster continuously the long term view. Responsive governance mechanisms are required that will provide:

  - Continuity over time.
  - Coordination across jurisdictions.
  - Coordination with other-lake related activities, including land use planning, when required.

- Governance processes could provide the medium for enriching and catalyzing the processes of goal formulation, development of directions for action, and implementation. They could be structured to integrate, at all levels, the three critical functions of:

  - Continuously assessing current conditions and developing future directions and goals.
  - Integrating planning and other activities such that overall synergy is maximized and potential conflict between particular courses of action is reduced.
  - Operating and managing specific agreed upon activities.

- Governance processes should be structured so as to balance effectively local autonomy with the need to integrate actions for the common good.

  - Decentralization of decision making and action ought to be fostered and strongly encouraged.
  - At the same time, sufficient authority must be vested at the appropriate level so as to ensure that effective integration takes place and that long term objectives are not compromised.

- Governance processes should be so designed that they encourage effective participation and allow for an appropriate role for the various stakeholders and relevant interest groups:

- Appropriate access to a fair governance process is important for ensuring both that wise decisions are made and that decisions reached will be accepted and followed.

- Governance processes can provide an appropriate platform for various interests to express their views, positions, desires, and needs.

- Governance processes could provide an effective forum where conflict resolution and negotiations take place as part of a broad based decision making process.

o In view of the complexity of fluctuating water level related issues and the implications of their ecosystemic context, the role of governance might be expanded to include:

  - Developing new knowledge and technical information about pertinent fluctuating water levels related issues.

  - Providing such information to the various interests so that they can better assess available options and risks.

  - Assisting local authorities and other major stakeholders in planning.

  - Educating the public about broader system-wide effects of human activities.

  - Promoting new ideas and new approaches to planning and management as knowledge about the lakes basin and its integral components increases.

Governance mechanisms must evolve to match the complexity and variety of the tasks required for effective management of both quality and quantity related issues. Enriching governance processes that are already in place and providing for better linkages between existing capabilities that operate in relative isolation could enhance the likelihood of overall success.

PREREQUISITES FOR EFFECTIVE MANAGEMENT

In summary, taking a whole system perspective of levels related issues enlarges the view from a focus on specific isolated measures to a broader view of management and its related processes. In this regard, important prerequisites for achieving reasonable progress include the following:

- Agreements -- at all appropriate levels of concern about what should be accomplished.
- Strategies -- laying out the overall direction for action and specifying the general means of how objectives would be accomplished.
- Governance mechanisms -- facilitating continuity, participation and coordination, and mediating processes of planning, decision making, and implementation.

As these essential prerequisites take shape and evolve, discussion, development, evaluation, and implementation of specific measures can proceed in the most effective manner, ensuring that adverse effects of fluctuating water levels are reduced while minimizing discontent among the various existing interests and making it more likely that long term future needs are met.

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