April 20, 2006

International Lake Ontario-St.Lawrence River Study

Study Directors' Response to the

December 2005 National Research Council/Royal Society of Canada Retrospective Review of the LOSLR Study

Introduction

This is the response of the Study Directors and technical working group managers of the Lake Ontario St. Lawrence River regulation study to the National Research Council/Royal Society of Canada December 2005 *Review of the Lake Ontario St. Lawrence River Studies*. The International Joint Commission sponsored this independent NRC/RSC peer review of the LOSLR Study. The Commission asked the Study Board to respond to the NRC/RSC recommendations both for their own edification and to provide a sense of what the key issues are for future implementation. The Study Board believes that the NRC/RSC review comments and recommendations have value beyond this Study and are applicable to other comparable initiatives either underway or planned. After a brief discussion of our overall impressions of the NRC/RSC report, we address each finding and recommendation in detail.

Our primary conclusion is that the NRC/RSC perspective and approach to the review was highly theoretical and did not fully recognize the practical nature of this large public study. There are many acceptable paths to planning, formulating and analyzing the physical, ecological, social and economic attributes of resource management alternatives. Each discipline involved in the Study brought their own variants of acceptable analytical techniques and methods. There is no single, fixed template for such multi-disciplinary, comprehensive analysis as is recognized by the U.S. Water Resources Council's "Principles and Guidelines for Water and Land Related Resources Management" (WRC P&G; 1980).

As a result of the focus of the NRC/RSC, it is our opinion that the NRC/RSC did not sufficiently respond to the overarching charge given them by the International Joint Commission (IJC). The IJC asked the NRC/RSC to "evaluate the appropriateness and sufficiency of the studies and models used to inform decisions related to regulation plan options." In simplest terms, all studies and models have some level of error and uncertainty, the question is whether those errors and uncertainty are enough to mislead the decision. The NRC/RSC committee, while identifying an appropriate list of concerns did not do the analysis necessary to determine the effect their concerns might have on the decision about a new regulation plan. The Study Board acknowledges that it may have been too much to ask given the limited amount of time the NRC/RSC had for the review, but the NRC/RSC report should have acknowledged this. We fear that many readers will assume the NRC/RSC concerns could undermine the usefulness of the study. The Study Board did do the analysis and we believe the models and studies the NRC/RSC reviewed provide an appropriate and sufficient basis for selecting a new regulation plan. This was a study focused on decision making, based on information and models on hand - not on research, or on employing the latest analytical methods favored by any one discipline. The review came up with sensible evaluation criteria that reflect the best of contemporary analytical practices, and those insights will be useful for the next round of analysis, but they fall short of assisting with the primary charge raised by the IJC.

The Study Board believes that independent peer review is an essential component of public decision making, particularly where there is a considerable technical and scientific component that underlies the decisions of whether to undertake new regulation measures. The Study engaged in an intensively interactive and fully transparent public participation approach. The Study additionally sought external expert advice and peer review on all of the technical elements that the NRC/RSC reviewed. Almost all of the issues that were raised by the NRC/RSC were discussed by the Study Board, the Technical Working Groups (TWG's) and the Public Interest Advisory Group (PIAG) at some point during the course of the study. All were addressed to the satisfaction of the Study Board who were the decision makers in this process, and who guided the scientific, methodological and technical requirements for this Study. Throughout, there was concentrated effort and adjustment by the Study Board to seek a balance between employing the best available professional practices, state of the art methods and improved models, while conducting as rigorous a scientific approach as possible to meet the need for decision progress towards study goals.

Differences of opinion between the NRC/RSC Committee and the conduct of the Study are expected, as there are always differences between groups of experts on how to address a common set of fairly complex issues. However, some of these differences of opinion could likely have been addressed if the review committee had spoken to study scientists and modelers after drafting their initial concerns. The NRC/RSC review committee was made up of highly regarded U.S. and Canadian scholars in the appropriate fields, and we found their review without malice. The committee asked reasonable questions, but in many cases we asked the same questions and engaged experts, decision makers and the public to develop an answer. This was a mid-study review and the Study Board readily admits that not all of the documentation was complete at the time of the review. This is why it was even more important for the NRC/RSC to have engaged study researchers in more thorough discussions and inquiry. Now that the Final Report has been completed, many of the short-term questions and issues raised by the review committee have been substantively addressed and accounted for.

In sum, the Study Directors believe that none of the concerns raised by the NRC/RSC challenge the "appropriateness and sufficiency of the studies and models used to inform decisions related to regulation plan options." We found that the review committee conclusions fell into four broad categories:

1. The NRC/RSC finding was reasonable and the Study Board has addressed it.
2. The finding was limited by the information the NRC/RSC committee had before them, either because it was not available or because the Study Board was not asked to provide it.
3. The finding reflects an unresolved difference of professional opinion between the NRC/RSC committee and the Study Board
4. The finding was reasonable in the abstract, or as a scientific principle but wasn't relevant in a practical sense for the purposes of conducting the Study

Detailed comments on each NRC/RSC finding, including the numbered categorization of that finding, follow.

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US Study Director

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	NRC/RSC	Study Directors Response
Finding 1	1. LOSLR studies and models expand interdisciplinary scientific inquiry on the potential environmental effects of water level and flow regulation options in the Lake Ontario-St. Lawrence River Basin in ways that are useful for informing some aspects of decision making.	Category 4. The finding was reasonable in the abstract, or as a scientific principle but wasn't relevant in a practical sense for the purposes of conducting the Study. The NRC/RSC Committee did not evaluate how the soundness of the decision would be affected by any of its criticisms, or even suggest a framework for doing the evaluation, so its first finding is unsupported. In fact, the Board did these evaluations quantitatively and feels few policy decisions of this nature have ever been better informed by a study. Nonetheless, the Board also discovered that only small adjustments to economic outputs of the current plan are acceptable to the public and for some plans, for Lake Ontario coastal damages and for Lake Ontario wetlands (the areas we asked the NRC/RSC to review), these very small differences may sometimes be the same size as the likely error in the models. The IERM clearly establishes the superiority of Plan B+ for wetland and related benefits, but the small gains the IERM estimates for Plans A+ and D+ are within measurement error of the model. FEPS clearly establishes that all candidate plans will have roughly the same effect on coastal properties, and that further meaningful reduction in coastal damages from the current plan is not possible. But sensitivity analyses have shown that small changes in one key FEPS assumption could, while not changing plan rankings for Lake Ontario coastal damages, eliminate or increase the estimated damages of Plan B+. Regarding the NRC/RSC's first sentence in this finding, the study clearly expanded the inquiry on economic effects, as well, quantifying impacts in many categories for the first time.

Finding 2	2. The scientific foundations of the studies and models presented for review vary widely in empirical support, and overall, need stronger and more consistent quality control, quality assurance and treatment of error and uncertainty to inform decision making. Three evaluation criteria were used to assay the scientific foundations of the LOSLR studies and models presented for review: EC-1: Empirical support, EC-2: Quality assurance, and EC-3: Treatment of error and uncertainty.	Some of the NRC/RSC Committee's criticisms were correct and we have worked to address them. Exceptions are noted for each evaluation criterion.
Finding2 EC-1	In the LOSLR Study documents reviewed, empirical research was conducted in coastal and environmental (wetlands, species at risk, and IERM) investigations, and some problems were noted.	Category 4. This finding was reasonable in the abstract, or as a scientific principle but wasn't relevant in a practical sense for the purposes of conducting the Study. The Board intensively managed the scopes of work for the IERM and FEPS models and limited empirical data collection to those areas the Board felt were needed to support the decision. Those scoping decisions were challenged and reviewed by stakeholders, Board members, and experts in and outside the study. The NRC/RSC Committee is certainly no less expert or prestigious than the experts who partook in the internal debate, but the Committee had far less dialogue with the study members. Many of the committee's perceptions might have changed had they simply called the study team on the phone to ask why scoping decisions were made.
Finding 2 EC-1	In the coastal research (FEPS model and sub-models), a detailed land use parcel database was developed, but that database differs in completeness for Canada (-75 percent coverage) and the USA (-100 percent coverage), but neither the means to complete the Canadian database nor actions to account for these data gaps were included in the documentation.	Category 2. The finding was limited by the information the NRC/RSC Committee had before them, either because it was not available or because the Study Board was not asked to provide it. Expert and stakeholder opinion confirmed that changes in coastal damages would be negligible in the areas where data was not available. The Board rejected the expense of gathering data that would have no effect on the decision.

Finding 2 EC-1 (Cont')	The wetlands studies provided detailed accounts of empirical sampling, which allowed for detailed evaluation of this work. However, wetland sampling appears to have been limited primarily to shallow water sites; it excluded or undersampled deeper –water wetlands, which may have resulted in an underestimation of high quality habitat associated with deeper water wetland ecosystems. A second question in relation to the wetlands work was the degree to which the sampled wetlands are representative of wetland vegetation types across the LOSLR shoreline. The reviewed documents do not present evidence that wetlands were selected randomly, and quantitative methods were not documented to show how findings in the sb-set of wetlands that were sampled can be extrapolated to LOSLR wetlands in general.	Category 4. The finding was reasonable in the abstract, or as a scientific principle but wasn't relevant in a practical sense for the purposes of conducting the Study The wetlands study design called for sampling elevations that would respond to flooding and dewatering events. Sampling deeper water ecosystems would serve no purpose as these sites have not been dewatered in over 68 years and are unlikely to be affected by regulation. Bathymetric data was gathered to sufficient depths to allow for assessment of changes in water levels under all supply sequences, including climate change scenarios. It is the professional judgment of study researchers that there is no deficiency in the data gathered for assessing the differences between regulation plans. While random site selection would be the optimum for a scientific study of all Lake Ontario wetlands, practically, there was no real opportunity to make a random selection. Site selection was purposely restricted to best address regulation issues, based on available data, the amount of human disturbances affecting wetlands, and the ability to gain access. The study team spent three weeks carefully selecting four study sites of each geomorphic type in each country that were most representative of all those that were visited or reviewed from air photos or reviewed from an aerial flight along the shoreline in a small plane. It is the professional judgment of the study researchers, supported by the Study Board that the representativeness of sites chosen was not compromised by the selection process.

Recommendation EC-1	As no new data can be collected in the near-term, LOSLR study final reports should identify limitations of empirical data and information sources, data gaps, and sampling problems, and discuss their implications for decision making. For the longer-term, research to correct data and model deficiencies, including replacement of regression equations with process models, should be prioritized.	There is much more documentation than the NRC/RSC realized; and significantly more documentation is provided in the PFEG report. The NRC/RSC review has been helpful in determining where documentation should be improved. But faith in the study among decision makers and stakeholders is really based on their immersion in the shared vision process. In that process, advocates help shape scopes of work, review work products, and challenge the conclusions drawn from them. That process led to substantial critical attacks on the FEPS, IERM and SVM models that were resolved either by changing or explaining the models. Despite their expertise, the NRC/RSC Committee did not have the time or money to discover the modeling issues the study team had identified as most likely to cause doubt about the decision on a new regulation plan. Instead they raised intelligent questions as expert newcomers might, but did not call to ask if we had raised those same issues. The committee's concern that the study used regression models rather than hydrodynamic models is addressed in this Executive Summary recommendation, but their findings on this subject are included only in Chapter 2, review of the SVM. This is a Category 3 comment, reflecting an unresolved difference of professional opinion between the NRC/RSC committee and the Study Board. Briefly, we believe the NRC/RSC is incorrect in their assumption that regression models are less accurate within the range of water conditions modeled. The concept of an uncertainty analysis in which the probable error of the entire model is calculated using a Monte Carlo simulation makes sense when constructing a model of systems that do not exist (such as the estimate of overtopping a new levee that changes channel dimensions and roughness) but in this case, the regression models we use were based on over forty years of use in regulating releases; in simplest terms, we know how high the water will be when the flow is this much and the tide is this strong. Because of the requirement that no stakeholder group could suffer disproportionate damages, the candidate plans have relatively similar average and hundred year elevations and flows. We carefully compared the simulated water levels to actual historic water levels and even considered how hydraulic modeling errors would propagate into misestimated benefits. A hydrodynamic model would have had to have been calibrated to the same historic data, an enormous challenge based on the physical size of the system and the complicated flows in the St. Lawrence River.

Recommendation EC-2	Recommendation: In the short-term, LOSLR final reports should inform decision makers of the types of quality assurance measures that were and were not undertaken and discuss their potential implications for decision making.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it.
Recommendation EC-3	Recommendation: Future studies of water level regulation effects in the LOSLR basin should develop a comprehensive approach to uncertainty analysis.	Category 4. The finding was reasonable in the abstract, or as a scientific principle but wasn't relevant in a practical sense for the purposes of conducting the Study. The underlying principle that the Study Board and NRC/RSC agree on is that future studies should be designed and funded to address areas of uncertainty that are most likely to mislead policy makers, whether or not that fits the NRC/RSC's concept of comprehensive. The uncertainty analysis for hydrologic and hydraulic estimates is discussed above. Uncertainty analysis for each economic benefit category varied based on the nature of the studies and the way the results were used in the decision process. This material was not documented in time for the NRC/RSC Committee to review, but is included in the report from the PFEG.

Finding 3	3. The LOSLR models and studies reviewed here do not adequately integrate and display the key information needed for comprehensive evaluation and understanding of the tradeoffs among the candidate regulation plans. This conclusion is based on the following four review criteria (EC-4, 5, 6 and 7):	
Finding 3 EC-4	EC-4. Linkages and Feedback Among Related Studies and Models The SVM compiles first-order effects on environmental, coastal, and other indicators generated by FEPS, IERM, and other models. But: • as the IERM user's manual indicates, it is not an ecosystem model that incorporates the feedback effects of water level variation on species and habitat conditions. Instead, it compiles initial impacts (first-order effects) on performance indicators, and it is thus an impact accounting model rather than an ecosystem model.	Category 4. The NRC/RSC finding was reasonable in the abstract, or as a scientific principle but wasn't relevant in a practical sense for the purposes of conducting the Study. We agree that the IERM was not an ecosystem model, but we also believe that research costs to attempt such a model would certainly have been much greater and it is unlikely the effort would have better informed the decision. That is because to establish the effect of water levels on these higher order impacts, we would have had to collect data on all the things besides water levels (fishing, predation, invasive species, pollution, natural population cycles, etc.) that would define them, and the datasets would have to span enough years to allow mathematically sound regressions that would establish how the system worked. The Study Board had little doubt that this would be very expensive and the results would be inconclusive. The research modeled in the IERM convincingly showed that Lake Ontario wetlands not constrained by development and pollution would have more diverse plant life under more natural regulation, such as provided by Plan B+. The IERM also showed a secondary effect, that wetland birds now at risk would have better breeding and nesting habitat. The effect on coastal fish was harder to establish based on our research, but it appears that Northern Pike young-of-year net productivity would improve in the Upper River under Plan A+ and B+. Determining how increases in net productivity would translate to increased populations would require more research on the effects of predation, invasive species, and pollutants. For example, the case for Plan B+ would have been strengthened if we could have demonstrated that creating ten percent more young Northern Pike would increase adult populations by some percent and that in return would support larger sport fishing populations, connecting boating with the environment. But each successive impact would have required more research with less hope of isolating the effect of water levels.

Finding 3 EC-4	• In terms of model linkages, the FEPS model alters the bathymetry of shoreline environments, but those bathymetric changes were not fed into the IERM to vary wetland inundation, which could be used to model vegetation, shoreline habitats, and other environmental performance indicators associated with water level variation. These vegetation changes could have feedback effects on sediment transport and coastal erosion.	Category 4. The NRC/RSC finding was reasonable in the abstract, or as a scientific principle but wasn't relevant in a practical sense for the purposes of conducting the Study. The barrier-beach, drowned-river-mouth, and protected embayments are not subject to lake-related erosion events and bathymetric changes. There are wetlands there because they are protected from wave attack. Even the open embayments are largely protected from wave attack and changes in bathymetry; if they were not, there would be very little wetland vegetation.
Finding 3 EC-4	• External model linkages do not include economic and demographic scenarios that are relevant for evaluating candidate water regulation plans to replace Plan 1958DD. For example, real estate values of coastal property continue to rise at rapid rates, and the demand for different water and related land uses is changing, but the SVM does not incorporate such scenarios in its structure.	Category 4. The NRC/RSC finding was reasonable in the abstract, or as a scientific principle but wasn't relevant in a practical sense for the purposes of conducting the Study. The Study Board carefully considered and rejected the idea of forecasting studies for many reasons, chief among them was the nature of the decision – the Board's charge was to change regulation rules, not to build a new structure whose impacts would essentially be irreversible. Expert opinion was solicited about future changes in each element of the study and the potential consequences considered, sometimes leading to a mathematical analysis of how sensitive the decision was to future changes. Using the NRC/RSC example, an increase in property values will increase flooding damages, but they are very small under any of the candidate plans. Erosion and shore protection damages, on the other hand, are based on the costs of shore protection structures, not homes, and these benefits change in proportion to the same general price indexing that would affect other benefits. The PFEG report documents these decisions, but they were debated and well vetted with stakeholders, experts, the Study Board and the panel of economic advisors. Had there been better communication with the NRC/RSC committee, they could have at least factored this into their review.

Finding 3 EC-4	This report acknowledges that some of these linkages and feedbacks require knowledge beyond the current limits, and that fact should be discussed in the final reports and presentation of SVM results. However, other linkages and feedbacks between the SVM and its sub-models, and externally between the SVM and scenarios of socioeconomic change, could have been addressed. The reviewed studies and models make progress toward comparing the effects of regulation plan options, but the comparisons do not provide a comprehensive basis for evaluating and understanding trade-offs among regulation plan options.	Category 3. The NRC/RSC finding reflects an unresolved difference of professional opinion between the NRC/RSC committee and the Study Board. There was remarkable consensus, although not unanimity, among decision makers, experts and the public that the study measured the things that were important and possible to measure. This was the result of years of debate and collaboration in the development and management of scopes. The NRC/RSC offers no linkage or feedback that were not discussed and rejected by the Board after this kind of debate and collaboration with all parties.
Recommendation EC-4	In the short-term, the LOSLR final reports should inform decision makers of what has, and has not yet, been accomplished in the way of integrated water and environmental systems modeling. As part of an ongoing program, a LOSLR modeling system that dynamically links and reflects feedback among sub-models is recommended.	Category 3. The NRC/RSC finding reflects an unresolved difference of professional opinion between the NRC/RSC committee and the Study Board. There are certainly feedback mechanisms that, if well understood, would probably strengthen the argument for or against more natural regulation. The Board has identified some of these for inclusion in an adaptive management plan if the difficulty and expense of conducting research that would support a credible model could be overcome (for example, by fortuitous funding for some other related purpose).

Finding 3 EC-5	EC-5. Spatial and Temporal Resolution and Scaling Scaling issues in the Lake Ontario-St. Lawrence River basin are challenging. The LOSLR studies involve a wide range of spatial and temporal scales, which raise a number of concerns. For example, although more detailed hydrologic time series and station data are available at multiple locations on Lake Ontario and at a finer time step than the quarter-month period, the STELLA model in the SVM generates a single series of quarter-monthly values for the level of Lake Ontario, based on historical water management practice. Use of these single series values can result in a loss of precision, as the quarter-month does not provide enough temporal variation for many environmental impacts, including fish, SAR, and wetlands. This coarse time step was recognized as a potential problem in the LOSLR Plan of Study, which called for a 2D hydrodynamic model for the St. Lawrence River that operated on fine enough time scales to supplement the quarter-monthly time step generated by the SVM. As noted earlier, the LOSLR approach of using quarter-monthly values in Lake Ontario to calculate water levels for selected stations in the upper St. Lawrence River through regression analysis is inferior to hydrodynamic flow routing, and the combined use of regression and hydrodynamic models in the LOSLR Study needs to be more fully explained. The FEPS model uses lake level elevations along with a grid of wind and wave fields that erode and flood individual shoreline parcels and reaches, the results of which are then aggregated back to lake-wide effects.	Category 3. The NRC/RSC finding reflects an unresolved difference of professional opinion between the NRC/RSC committee and the Study Board. The “coarse timestep” is well matched to the decision in question: How much should the average release for the week be? Most of the within week variations will be driven by other factors, such as natural variation in tributary contributions, operation of the power plants, changes in temperature and the like. A finer timestep – daily or hourly – might give the impression of precision, but to be accurate, that model would require daily or hourly flows. Since these models are meant to evaluate how a new regulation plan will affect things – the model is not an academic exercise to replicate what happened in the past - the results of the model would then be applicable to that particular sequence of hourly events. To make sure a plan would work in the as yet unknown future, many alternative sequences would have to be run, each with different tributary flows, temperatures, and other factors. This task would be overwhelming and it would be difficult to demonstrate that enough combinations had been sampled. This is a well known problem in studies such as this, and the typical solution is to use historic data sets with short timesteps for issues like flooding, and long time steps for issues like water supply. This again tests a plan against a very limited set of circumstances. Our solution was tailored to meet each different need. For river flooding, quarter-monthly average levels were correlated with hourly peaks based on historic data, so the flood damage was based on a probabilistic estimate of hourly levels. Lake Ontario flooding used an even more complex combination of quarter-monthly levels and statistical estimates of wave and surge levels. Navigation delays were calculated based on regressions from historic data on the percent of time the slope between two gages would exceed safety limits based on the average quarter-monthly slope between those two gages. Similar probabilistic methods were used in the environmental studies.

Finding 3 EC-5 (Cont')	The errors and uncertainties associated with these different resolutions and scales of inquiry need fuller analysis and discussion, as errors may exceed the differences among model outputs for some performance indicators and plans.	Finally, where possible, the model results were compared to historic results to verify that we had combined the medium and short term effects properly. The FEPS model was run using 1960-2000 data and the results for one Canadian and one U.S. reach were compared to the actual erosion that occurred based on interpretation of aerial photographs, and in both cases, the model estimate was within 10% .of the actual values. There are many more examples, and these have or will be provided to the IJC. But the Committee's conclusions on these two criteria are not just reflective of the fact of these acknowledged shortcomings to date, they are misdirected because the Committee conceptualization does not fit within the context of public policy decision making.
Recommendation EC-5	Recommendation: In the short-term, the LOSLR final reports should inform decision makers of temporal and spatial scaling issues that affect the accuracy and uncertainty of predictions of regulation effects. In the longer term, choice of time step should better reflect the critical response times for system indicators, including those where transient fluctuations in water temperature and water level are critical and appropriate hydraulic and hydrodynamic modeling approaches should be implemented.	Category 2. The NRC/RSC finding was limited by the information the NRC/RSC Committee had before them, either because it was not available or because the Study Board was not asked to provide it. Had we known they were concerned about timestep issues, we could have provided them more of our rationale.

Finding 3 EC-6	EC-6. Thorough Documentation . Of the ten criteria employed in this review, inadequate documentation is the most apparent deficiency, with examples Fortunately, this deficiency can be corrected in the near term. throughout the materials presented for review. FEPS included more detailed descriptions of modeled performance indicators than other studies, but did not document the models themselves. Descriptions of wetland methodologies need additional information about site selection and means to ensure adequate representativeness of sampled sites. A user's manual exists for the IERM and provides partial documentation, but explanations of weighting and aggregation in the model are insufficient. Exceptions to these general patterns include the Species-at-Risk 3A and 3B reports, which are well documented. Better documentation is needed to explain choices of what was done and methods used, and the rationale behind those decisions. The SVM is the primary tool for understanding and evaluating trade-offs among potential regulation plans. It was surprising, therefore, that the SVM had the least amount of documentation presented for this review, and the documentation that was presented was not at a level of completion ready for external scientific review. Documentation of the SVM should have a more complete discussion of its role in the Shared Vision planning process; describe SVM development and refinement, including standard technical documentation of all component models and describe how scientific and stakeholder criteria were used interactively to formulate, screen, and evaluate the range of choice among regulation plan options.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it. The NRC/RSC need for documentation was commensurate with their role as outside auditors. Study members, even representatives from the public, were so involved with scoping and execution that their documentation needs were smaller and met in different ways (such as the free use of STELLA software and access to Study Board meeting documentation). Much of this documentation was available online and could have been provided had the NRC/RSC Committee asked. However, people who use this study in the future will be in much the same position as the NRC/RSC Committee, and will require better documentation, especially for the STELLA model. The PFEG Report uses the NRC/RSC review as one guide.

Recommendation EC-6	Recommendation: In the short-term, LOSLR final reports should include a thorough documentation of studies and models, especially the Shared Vision Model, and seek further independent scientific review of those reports.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it.
Finding 3 EC-7	EC-7. Effective Scientific Communication Effective scientific communication is achieved when scientific information is presented to and received and correctly understood by scientific, public, and decision making groups. The efficacy of scientific communication varies among LOSL: studies and models, as scientific information was communicated in many ways in the materials submitted for review. Performance Indicators; an Index of Ecological Integrity; and documentation of studies, models, and sub-models are some of the items used to communicate scientific information from the LOSLR Study. In general, the environmental studies and performance indicator summaries were easier to understand than the sub-models' documentation, and sub-model documents were more digestible than the SVM documentation. An example of deficient, or even misleading, communication is the differential treatment of economic and environmental indicators in which the former are presented as simple values while the latter are subject to a +/-10 percent error. The LOSLR Study's display of model output in a spreadsheet file of tables and graphs, known as the "Board Room," has strong potential as a venue for scientific communication.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it. The Board Room is used by almost everyone in the study, and has been designed to meet every individual need for information. Hyperlinks in the Board Room connect to documentation for every performance indicator and every plan. The decision criteria used by each Board Member and the decision guidelines used corporately by the Board are available in the Board Room , with each criterion hyperlinked to every related performance indicator and hydrologic attribute. Study members were given copies of STELLA and many participated in the design of the model, and many either built or were intimately familiar with the coding used. Those members helped other members build trust in the model. The STELLA model uses documentation at the sub-system level and for most of the individual variables. To further improve on scientific communication, the PFEG report includes the so-called "story of regulation" that explains what we understand about the operation of this system after years of study, and has detailed documentation and explanation of all major STELLA sub-models, including the Excel files linked to it as input or output.

Recommendation EC-7	Recommendation: In the short-term the LOSLR final reports should communicate their scientific results with transparency to support decision making while giving a full treatment of uncertainties and non-scientific dimensions of the studies. In the longer-term, the SVM may be refined for continuing use as a vehicle for scientific communication.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it.
Recommendation EC-7	Recommendation: In the short-term, the LOSLR Study should complete the conceptual narratives. For the longer-term, the IJC should consider an ongoing management and monitoring system to feed the results of current choices for water level regulation into a dynamic model of the LOSLR system to strengthen the scientific basis for future planning on a multi-decadal timescale, as outlined in the final recommendation below.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it. We have completed the contextual narratives, which are available through the Board Room. The Board recommended an adaptive management plan that could refine the SVM algorithms and possibly lead to changes in the regulation plan.
Finding 4	Despite the breadth of LOSLR studies and models, ongoing analysis is needed to provide a strong scientific basis for long-term decision making about water level and flow regulation in the Lake Ontario-St. Lawrence River basin. Three points support this conclusion. **First,** current knowledge about the lower Great Lakes system is not comprehensive. While the LOSLR studies and models broaden understanding about the potential effects of regulation plans, a more comprehensive data collection and modeling approach is needed to understand system feedbacks, linkages, and uncertainties. Ideally, a system dynamics model should be used to: (a) improve the physical system description; (b) identify the most important feedback relationships; and (c) improve understanding of feedback effects on system behavior. Some feedback relationships require expansion of the model boundaries so that key processes, ranging from coastal urbanization and regional economic growth to climate change, are incorporated and impacts are made visible within the model.	Category 3. The NRC/RSC finding reflects an unresolved difference of professional opinion between the NRC/RSC committee and the Study Board. While we agree that there is much still to know about the lower Great Lakes, no one in five years of study made a good case that a research project not done would substantially improve the decision. Nor has the NRC/RSC; they have pointed out that there are things we did not research or model, but they have not evaluated the effect that has on the decision. The study team (decision makers, stakeholders, and experts in and outside the study) did that analysis, often quantitatively. The error in our models (as explained in our response to NRC/RSC Finding #1) may be larger than some of the smallest differences between the candidate plans, but we feel confident, based on sensitivity analyses that plan rankings would not change with more accurate models. We also know that improvements in model accuracy and comprehensiveness (second and third order impacts in the IERM, the use of individual shore protection structure data in FEPS) would be very expensive with questionable benefit. Adaptive management, with comparison of modeled and future impacts, is probably a cost effective way to gain modest improvements in model accuracy.

Finding 4	**Second**, the LOSLR history with Plan 1958DD shows that regulation plans can be superseded by newer, better plans, and change in management objectives. Any plan adopted now the basis of current science without provision for regular updating as knowledge advances is to require adjustments over time.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it. We have prepared an adaptive management plan action plan.

Finding 4	**Third,** the LOSLR models evaluate effects of future regulation plans and hydrologic scenarios primarily on historical and current environmental and social performance indicators. This is an important step forward, given the significance of hydroclimatic variability for water regulation and challenges of modeling current environmental and socioeconomic processes. Although this report does not review the climate change research and scenarios, it commends the LOSLR inclusion of global processes that affect the robustness of regional regulation decisions. In the future, however, regulation plan decisions will also require comparable scenario development and evaluation for other environmental and social processes. Changes in regional economic structure, demography, water demand, transportation technology, coastal land use, and socioeconomic values will likely transform the profile of stakeholder interests, performance indicators, and socioeconomic impacts associated with water level regulation. The past half-century indicates that these types of structural shifts in socioeconomic and environmental conditions and values, in conjunction with hydrologic variability, have had substantial implications for regulation plan decision making. The LOSLR studies and models begin to address these issues through brief conceptual narratives with a planning horizon of 10 to 15 years that are linked to the SVM. The conceptual narratives employ a common template, but they vary in detail, completeness, and level of peer review. Correcting the scientific and modeling deficiencies identified in this review is necessary and appropriate, but not sufficient, for informing water regulation decisions on a long-term multi- decadal timescale.	Category 1 and 4. We have done some of this, but the NRC/RSC finding is mostly reasonable in the abstract, or as a scientific principle but was not relevant in a practical sense for the purposes of conducting the Study. See comments on EC-4, above. Our analysis shows that many significant changes in regional economic structure would have little effect on regulation. For example, if the Seaway were to close, the requirements for water supply and the environment on the lower river would still call for the same basic operating strategy (store water on Lake Ontario that can be released during long droughts). Sharp increases in housing prices or the value of recreational boating experiences would change damages but not plan rankings. All candidate plans are constrained already to essentially minimize Lake Ontario coastal damages so that maximum Lake Ontario levels are much lower than the optimal for hydropower, navigation, or downstream water needs. The Board has done this analysis for all major issues, and has outlined an adaptive management plan for three factors that might subtly influence future regulation – Lake Ontario wetlands, bluff recession and boating problems.

Recommendation EC-10	EC-10. Identification of Future Study Needs As the LOSLR Study draws to a close in 2005, a unique opportunity is presented for a new approach to water level regulation in the LOSLR basin. Even after the deficiencies noted above are addressed, and a new regulation plan is adopted and implemented, the need will remain to monitor the system for responses to the new regulation plan. Long-term monitoring may also indicate needed adjustments to the plan. Adaptability is mentioned in the LOSLR "Vision, Goals, and Guiding Principles" in a number of ways: ". .. regulation plans will incorporate flexible management.. .;" "Regulation of the Lake Ontario-St. Lawrence River System will be adaptable.. .;" and".. .regulation plans will incorporate.. .flexibility to adapt.. .." An adaptive management program could help the basin constituents build upon the LOSLR studies and models over time. Before an adaptive management program is designed, the deficiencies noted in LOSLR models and studies need to be corrected to avoid perpetuating existing problems. The challenges of implementing an adaptive management in the Lake Ontario-St. Lawrence River basin should not be underestimated. Adaptive management can be resource intensive: an "active" adaptive management plan could involve annual costs comparable to those of the LOSLR study; "passive" adaptive management costs would be significantly lower, depending upon the scope of monitoring and management involved, but also less useful. Either way, adaptive management is seen as a viable option to build upon the LOSLR Study successes, address deficiencies, and maintain a responsive, flexible water regulation plan for the LOSLR basin.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it. Although we believe our fixed analysis to be fairly robust, we have designed an adaptive management action plan that could be used to improve our models and regulation over time.

	In the short-term, adaptive management alternatives should be identified that build upon the LOSLR studies and models. In the longer term, the IJC should, in collaboration with other scientific and stakeholder organizations in the basin, develop an adaptive management program that would provide a continuing scientific basis for monitoring the effects of water regulation, experimenting with alternatives, and thereby improving decisions about future regulation plan options.	Category 1. The NRC/RSC finding was reasonable and the Study Board has addressed it. The IJC has entered into informal discussions with other groups to this end.

	Looking Ahead: Adaptive Management in the LOSLR Basin As the LOSLR Study draws to a close in 2005, a unique opportunity is presented for a new approach to water level regulation in the LOSLR basin. Even after the deficiencies noted above are addressed, and a new regulation plan is adopted and implemented, the need will remain to monitor the system for responses to the new regulation plan. Long-term monitoring may also indicate needed adjustments to the plan. Adaptability is mentioned in the LOSLR "Vision, Goals, and Guiding Principles" in a number of ways: ". .. regulation plans will incorporate flexible management.. .;" "Regulation of the Lake Ontario-St. Lawrence River System will be adaptable.. .;" and".. .regulation plans will incorporate.. .flexibility to adapt.. .." An adaptive management program could help the basin constituents build upon the LOSLR studies and models over time. Before an adaptive management program is designed, the deficiencies noted in LOSLR models and studies need to be corrected to avoid perpetuating existing problems. The challenges of implementing an adaptive management in the Lake Ontario-St. Lawrence River basin should not be underestimated. Adaptive management can be resource intensive: an "active" adaptive management plan could involve annual costs comparable to those of the LOSLR study; "passive" adaptive management costs would be significantly lower, depending upon the scope of monitoring and management involved, but also less useful. Either way, adaptive management is seen as a viable option to build upon the LOSLR Study successes, address deficiencies, and maintain a responsive, flexible water regulation plan for the LOSLR basin.	

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