A Review of

"Upper Peace River: An Analysis of Minimum Flows and Levels"

August 25, 2002 Draft by:

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November 2002

EXECUTIVE SUMMARY

This is a summary of the Scientific Peer Review Panel's evaluation of the scientific and technical data, assumptions, and methodologies used by the Southwest Florida Water Management District in the development of its proposed minimum flows and minimum levels (MLFs) for the Upper Peace River.

To the best of its abilities, the Peer Review Panel has not only attempted to provide a critical review of the methods, data, and conclusions of the District, but has suggested a number of improvements and guidelines for future decisions on the restoration or rehabilitation of the Upper Peace River. We consider the proposed MLFs to be a good *first* step in the management process but can not be the *only* step.

The resource management goals for the Upper Peace River are to:

- Maintain minimum depths for fish passage and canoeing in the upper river
- Maintain depths above inflection point in the wetted perimeter of the stream bottom
- Inundate woody habitats in the stream channel
- Meet the hydrologic requirements of floodplain biological communities.

These goals represent a reasonable subset of potential goals for an improved biotic community in the degraded upper basin. The rationale for choosing these goals is clearly presented and scientifically justified.

In general, the wetted perimeter approach does an adequate job to predict levels that will address the management goals, as described. As an initial step, maintaining fish passage, that is, the connectivity of the system, is a necessary goal. The assumption of a desired elevation of the channel at its deepest point being 0.6 feet above minimum elevation for fish passage is reasonable. The application of the HEC-RAS model to generate a wetted perimeter versus flow plot for each transect also is a justifiable scientific approach.

In order to complete an effective program of *rehabilitation* of the upper Peace River, we suggest that the current management goals may not adequately address the linkages between instream flow-related (hydraulic) habitat requirements of resident biota and discharge conditions over the range of life-stages and functions of various species within the community. Future efforts to enhance the integrity of the upper Peace River may require that these linkages be established. We understand the constraints placed upon the current study and our comments are provided to encourage the District to frequently revisit this study and to view the establishment of MLFs and rehabilitation goals as a *dynamic* process that results in improved flow criteria as new data and techniques are acquired.

The approach the district adopted to investigate the relationship between floodplain systems and hydrologic patterns was reasonable and appropriate, based on the relationships presented in most of the published literature. However, in this system, the methods and analyses were not adequate to produce information that could be used to formulate recommendations regarding medium and high flow regimes on those surfaces. The District was correct in declining to recommend specific flow criteria for that purpose. Recommendations for future studies of this nature include collection of more detailed data and adoption of a broader perspective regarding options for ecosystem management and restoration, to include actions other than flow regulation.

No specific quality assurance measures are described in the report. However, it seems clear that a variety of experienced professionals, both District employees and consultants, were involved in project planning and subsequent field studies and analyses. If there was a failure in the quality assurance process, it was that the level of effort employed in the field studies was not carried through to data analysis and presentation of results. Much of the data collected are not presented or discussed in the draft report. In hindsight, it might have been a good idea to apply the "peer review panel" concept to the study plan development phase. This might have produced a more streamlined and more narrowly focused study plan.

The District has completed a comprehensive data set for application to the *wetted perimeter method* for minimum flow analysis. However, the question of "best available data to establish minimum flows" cannot be entirely evaluated. There are many alternative techniques for predicting or analyzing minimum flows in fluvial systems. Some of these techniques would require more comprehensive instream physical data than reported in this study. For example, the linkage between hydraulic habitat requirements of species' life-stages must be evaluated by an incremental evaluation, across each transect, of velocity, depth, and substrate/cover criteria as well as the development or acquisition of habitat suitability information for those target species. We do not know if these data were acquired as part of the generally excellent study design but not reported since they are not appropriate to a wetted perimeter estimate.

The Peer Review Panel has reviewed several techniques that it considers to be alternatives to the MLF procedures employed by the district. All of these techniques would require a greater effort in data collection and analysis; however, the panel feels that such an analysis would lead to more sound management strategies to maintain the integrity of the catchment ecosystems. Specifically, we suggest that the instream flow incremental approach (IFIM) might be considered as the next management step as a means of connecting physical habitat requirements and availability to the MLFs already established. The software for the IFIM technique is the physical habitat simulation (PHABSIM), which combines hydrologic records (from gauging stations along the river), direct measurements of conditions at the site, and biological information on the flow-related habitat requirements of various aquatic species. The output of the model is a prediction of the gains and/or losses of habitat with changes in discharge or with a proposed regulated flow regime. PHABSIM and IFIM are widely accepted as a basis for establishing acceptable flows to maintain the integrity of stream and river ecosystems. In general, instream flow analysts consider a loss of more than 15% habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage. The analysis is completed with a time-series analysis of a yearly daily hydrograph of the stream to determine which time intervals contain long-duration low-flow periods. These are considered to be "bottlenecks" in the success of the population are management targets. We suggest that such a technique could be used for a monthly allocation process that targets remediating poor-habitat-producing high-flow events in the Upper Peace River catchment.

As noted, one of the weaknesses of the District report is the ability to link maintenance of medium and high flows to maintenance of riparian floodplains. This linkage is a critical component for the maintenance of the integrity of the Upper Peace River catchment. We suggest that the ultimate goal for restoration of that integrity will necessarily be the recreation of that medium and high flows that establish these linkages. Regardless of the final management decisions and modeling techniques chosen by the district to achieve this goal, there are a number of so-called building block models to provide a way to more closely mirror original hydrologic and hydroperiodic conditions within the basin. We have presented several of these building block approaches and suggest that the District consider employment of these models as the *next* step in building upon an impressive and quite comprehensive data set.

INTRODUCTION

Under Florida statutes, the Southwest Florida Water Management District (SWFWMD) provides for peer review of methodologies and studies that address the management of water resources within the jurisdiction of the District. The SWFWMD has been directed to establish minimum flows and levels (designated as MFLs) for priority waterbodies within its boundaries. This directive is by virtue of SWFWMD's obligation to permit consumptive use of water and a legislative mandate to protect water resources from *significant harm*. According to the Water Resources Act of 1972, *minimum flows* are defined as "the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area" (Section 373.042 F.S.). A *minimum level* is defined as "the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." Statutes provide that MFLs shall be calculated using the *best available* information,

The process of analyzing minimum flows and levels for the Upper Peace River is complicated by the fact that this portion of the river has been affected by substantively reduced flows that extend back at least 40 years. Establishment of minimum flows and levels generally is designed to define thresholds at which further withdrawals would produce significant harm to existing water resources and ecological conditions if these thresholds were exceeded in the future. These thresholds have been exceeded regularly for decades in the Upper Peace River. Therefore, this report is focused upon determining the best scientifically defensible minimum flows and levels that if achieved in the future would reestablish improved river function and ecological conditions in the Upper Peace River.

This review follows the organization of the Charge to the Peer Review Panel, addressing the questions posed and offering supporting explanation, analysis, and recommendations for future management actions. It is the job of the Peer Review Panel to assess the strengths and weaknesses of the overall approach, its conclusions, and recommendations. This review is provided to the District with our encouragement to continue to enhance water resource management in the district and to strengthen the scientific basis for the decision-making process in the future.

1.0 THE CHARGE

The charge to the Peer Review Panel contains four basic requirements:

1. Review the District's draft document that outlines methods used to develop provisional minimum levels for the Upper Peace River.
2. Review additional documents, materials, and data supporting and/or criticizing the concepts or conclusions presented in the draft District document.

3. Participate in an open (public) meeting at the District's Tampa Service Office for the purpose of discussing directly all issues and concerns regarding the draft report with a goal of developing this report.

4. Provide to the District a written report that includes a review of the data, methodologies, models, and conclusions outlined in the draft report. This report will include suggestions for additional data acquisition or suggest alternative approaches to establishing MLFs for the Upper Peace River.

We acknowledge that some statutory constraints and conditions affect the District's development of MLFs and that the Governing Board may have also established certain assumptions, conditions and legal and poicy interpretations. These *givens* include:

1, the selection of water bodies or aquifers for which minimum levels have initially been set;

2. the determination of the baseline from which "significant harm" is to be determined by the reviewers;

3. the definition of what constitutes "significant harm" to the water resources or ecology of the area;

4. the consideration given to changes and structural alterations to watersheds, surface waters, and aquifers, and the effects and constraints that such changes or alterations have had or placed on the hydrology of a given watershed, surface water, or aquifer; and

5. the adopted method for establishing MFLs for other water bodies and aquifers.

In addition to the draft report and appendices, various types of supplementary data provided by the District were examined as part of this review. These included reports on the hydrology of the system, selected cited literature, raw and summarized vegetation data, and spatial information provided in a GIS format. The latter showed transect locations, topographic data and the distribution of National Wetland Inventory wetland types within the study area.

The draft report puts much emphasis on documenting historical influences on the river system, and thereby establishes a historic frame of reference for understanding the changes that have taken place over the past century. This approach has allowed a careful reconstruction of historic flow patterns, with an appropriate use of climatic data to isolate actual human influences from natural patterns of variation. In addition, the District has explicitly recognized that the concept of minimum flow (MLF) must necessarily encompass a variety of complex issues if it is to reflect a broader standard of ecosystem functionality and sustainability. We commend the District for taking this approach, and encourage continued emphasis on ecosystem integrity and process in future studies of this kind.

This review was undertaken with the understanding that the Upper Peace River system represents a worst case - the thorough historical overview and presentation of historical hydrologic data documents that this system is already far below any reasonable standard of ecological integrity. So, we wish to make it clear that we do not consider the standards of adequacy adopted or recommended in this report to be applicable to low-flow analyses that may be undertaken elsewhere in the region. In this case, we recognize that the District is dealing with a severely degraded system, and the focus is rightfully on halting the decline and beginning a slow process of recovery. This necessarily differs from other systems, where the aim would be to prevent degradation of functional systems.

All comments relative to instream habitat analysis as well as wetland and floodplain studies are provided in the context of the limitations put on these data in the report. That is:

1. The report concludes that the only recommendations that can be made at this time are for minimum flows at low-flow conditions. No specific flow criteria are recommended for floodplain and wetland systems; therefore many of the questions posed to the reviewers are not directly relevant to those systems.
2. Because of this, all comments relative to floodplain and wetland systems are directed toward the objectives of eventually formulating a recovery plan, and of improving the approach for conducting analyses in other systems.
3. Therefore, with regard to riparian systems, the comments of the reviewers are framed in terms of how future studies might be structured to take advantage of lessons learned during this effort. Basically, the question is, have these studies been pursued in the appropriate way to eventually be used in setting mid- and high-flow criteria? In the case of riparian vegetation communities, the studies undertaken were a reasonable first step toward understanding the riparian ecosystem and its interaction with the stream system. There are various deficiencies in procedures and presentation (discussed below) that should be rectified in future studies, but the effort demonstrated or indicated some important points:

    a. The hydrologic controls on floodplain forest composition and structure are complex, and analyses of historic hydroperiod and flood frequency patterns are unlikely to account for all of the community variation that exists or may occur in the future. Indeed, this recovery plan must, eventually, incorporate an analysis of an incrementally altered flow regime to address seasonal changes in overriding functional and ecological needs.

    b. The data collection procedures should be refined for future studies, with the goal of understanding how community composition and structure are maintained. More detailed vegetation data, and more attention to site characterization will be required if forest characteristics are to be a focus of future ecosystem assessment and management programs.

c. The recognition by the District that ecosystem integrity incorporates more complex concepts than simple "low flow" criteria should be expanded if ecosystem recovery is to be effective. While some ecosystem processes can never be fully restored, other elements of ecosystem function might be particularly responsive to management, even where hydrology is irreversibly altered. With regard to riparian systems, areas that might be appropriate for further investigation include spatial considerations (such as wildlife corridors), management to assure habitat continuity for wildlife species dependent on certain community types or successional stages, and a particular focus on sites and communities where aquatic and terrestrial interactions potentially can be maintained (such as cypress swamps). Attention to these and similar areas of inquiry may represent opportunities to partially restore and sustain the overall "health" of the riparian system even if full hydrologic restoration is not possible.

2.0 RESULTS OF THE PEER REVIEW

The draft report has established four Resource Management Goals:

- Maintain minimum depths for fish passage and canoeing in the upper river
- Maintain depths above inflection point in the wetted perimeter of the stream bottom
- Inundate woody habitats in the stream channel
- Meet the hydrologic requirements of floodplain biological communities.

The report stated clearly that a primary objective of setting minimum flows and levels is to provide adequate hydrological conditions for the aquatic biota of the Upper Peace River. The management goals include minimum depths for fish passage and canoeing, maintain depths above inflection points in the wetted perimeter of the stream bottom, inundate woody habitats in the stream channel, and meet hydrologic requirements of floodplain biological communities. These goals represent a reasonable subset of potential goals for an improved biotic community in the degraded upper basin. The rationale for choosing these goals is clearly presented and scientifically justified.

In general, the wetted perimeter approach does an adequate job to predict levels that will address the management goals, as described. As an initial step, maintaining fish passage, that is, the connectivity of the system, is a necessary goal. However, in order to complete an effective program of *rehabilitation* of the upper Peace River, we suggest that these goals may not adequately address the linkages between instream flow-related (hydraulic) habitat requirements of resident biota and discharge conditions over the range of life-stages and functions of various species within the community. Future efforts to enhance the integrity of the upper Peace River may require that these linkages be established. We understand the constraints placed upon the current study and our comments are provided to encourage the District to frequently revisit this study and to view the establishment of MLFs and rehabilitation goals as a *dynamic* process that results in improved flow criteria as new data and techniques are acquired.

The accompanying discussion appropriately distinguishes between the importance of maintaining periodic linkages between aquatic and floodplain systems (particularly focusing on productivity of both) versus the influence of "hydroperiod" in maintaining plant community mosaics. The stated approach is to focus on plant communities and associated periods of inundation. A separate effort is directed toward developing an analysis of the relationship between hydrologic zones and the life history requirements of selected fauna.

Our comments are framed in response to the Tasks established for the Peer Review Panel by the District.

Task 1: Determine whether the method used for establishing the minimum flows and levels is scientifically reasonable.

(a) Supporting Data and Information

The supporting data and information have been drawn from a variety of sources and summarized in the first three chapters of the report. The general supporting data include 1) basin characteristics, 2) hydrologic trends and water quality, and 3) ecological resources and key habitat indicators.

The basin characteristics include watershed location, climate and rainfall, physiography, river channel and floodplain morphology, hydrology and hydrogeology, and a chronology of watershed development. A useful map of the Peace River drainage basin is presented (Figure 2-1) that locates the catchment, urban areas, the upper basin, and the USGS gage sites. The climate and rainfall data are comprehensive and provide a reasonably long-term record back to 1940. Physiographic provinces are derived from a geomorphic analysis by White (1970). Larger scale river channel and floodplain morphology come from USGS elevation surveys in the region. Hydrology and hydrogeology data are compiled from reports from the SFWMD and USGS, and these data provide a good overview of regional hydrology and hydrogeology. The chronology of watershed development is thorough and a useful overview to the changes that have occurred in the Upper Peace River from 1800 to the present. We agree that the background data on basin characteristics is a thorough compilation and scientifically reasonable.

Hydrologic trends for discharge and water levels are based on three USGS gage sites in the Upper Peace River basin. The Peace River gage dates from 1939, the Fort Meade gage from 1974, and the Zolfo Springs gage from 1933. Data quality for discharge is estimated at an accuracy of 5-8%. Trends can be accurately determined, especially from the two gages with records back to the 1930s. There also is a series of reports and papers dating from 1990 that document declining flows in the Peace River. Analyses methods and statistics are reasonable and properly applied. Exceedance flows were used to examine long-term trends, and these analyses strongly support the conclusion of declining flows in the Upper Peace river basin particularly from the 1980s to the present. Water levels also declined significantly over the period of record and are analyzed correctly.

The draft report also analyzed the factors affecting flow in the Upper Peace River. Declines in the artesian aquifer levels in the Upper Peace basin are large for peninsular Florida and contribute significantly to declining flows. Other factors such as long-term changes in rainfall, groundwater withdrawals, wastewater discharges, and structural modifications within the basin also are presented in depth. We particularly commend the District for a thorough and perceptive analysis of climate variability that impacts rainfall and runoff at the decadal time scale. These longer-term effects on precipitation and discharge are beginning to be linked to sea surface temperature patterns worldwide and are important when examining long-term trends. The analyses of the four sub-basins that make up the Upper Peace River basin (Peace Creek, Saddle Creek, Zolfo Springs, and Payne Creek) are informative and rigorous. We strongly concur that the proposed minimum flows will require some type of recovery as the data show that they are not presently being met.

Water quality also is considered in the draft report. Total phosphorus levels in the Upper Peace River are exceptionally high due to the parent geology of the region and extensive phosphate mining in the basin. Increased agricultural impacts on water quality are indicated by the highly significant increase in solute concentrations of potassium through time. In general, data support the interpretation that improving water quality in the Upper Peace in recent years is linked to a reduction in mining activity and improved wastewater treatment.

Given the objectives of the study, data collection for the riparian zones was approached in an appropriate way. The historic analyses of hydrology and designation of hydrologic "zones" along multiple transects was a good way to establish a framework for subsequent investigations of plant distribution and animal life history analyses. Although neither of these latter studies was able to answer many of the questions they were intended to address, they were reasonable first steps in what will be a stepwise, adaptive learning process. Basically, if the vegetation and soils studies are viewed as a pilot effort intended to guide future work in this basin and others, then the data collection approach was reasonable.

No specific quality assurance measures are described in the report. However, it seems clear that a variety of experienced professionals, both District employees and consultants, were involved in project planning and subsequent field studies and analyses. If there was a failure in the quality assurance process, it was that the level of effort employed in the field studies was not carried through to data analysis and presentation of results. Much of the data collected are not presented or discussed in the draft report. In hindsight, it might have been a good idea to apply the "peer review panel" concept to the study plan development phase. This might have produced a more streamlined and more narrowly focused study plan.

The only explicit "exclusion" of data discussed in the report concerned the parsing of historic flow data to exclude periods of anomalous rainfall patterns. This appears to be a reasonable thing to do. With regard to the vegetation data, some analyses and discussion that would have been anticipated based on the data collection methods did not appear in the report. Specifically, there was little reference to the understory and seedling composition data, which presumably were collected specifically to examine patterns of change in response to altered hydrology and hydroperiod.

The District has completed a comprehensive data set for application to the *wetted perimeter method* for minimum flow analysis. However, the question of "best available data to establish minimum flows" cannot be entirely evaluated. There are many alternative techniques for predicting or analyzing minimum flows in fluvial systems. Some of these techniques would require more comprehensive instream physical data than reported in this study. For example, the linkage between hydraulic habitat requirements of species' life-stages must be evaluated by an incremental evaluation, across each transect, of velocity, depth, and substrate/cover criteria as well as the development or acquisition of habitat suitability information for those target species. We do not know if these data were acquired as part of the generally excellent study design but not reported since they are not appropriate to a wetted perimeter estimate. We offer comments on alternative study designs for the future in our Task 3 response, below. With respect to floodplain communities, this is a moot question since no relevant flow criteria were recommended. However, the report states that there is intent in the future to address medium and higher flows relevant to floodplain systems, and there are a number of possible avenues to be explored in future studies (see Task 3 response, below).

(b) Technical Assumptions

The technical approach for establishing minimum flows and levels included field studies and hydraulic modeling. The hydraulic modeling and statistical analyses of stream flow records were coupled with the field studies of river transects in the Upper Peace Basin to evaluate fish passage depths and the inflection points for the wetted perimeter of the channel. The hydraulic modeling used the HEC-RAS model developed by the US Corps of Engineers. This is a relatively new model and is typical of growing number of *unlinked* models using hydrographic techniques to estimate minimum flows (Gore and Mead 2002). We consider the HEC-RAS model an appropriate tool for assessing flow-stage relationships at various points along the river. The assumption of a desired elevation of the channel at its deepest point being 0.6 feet above minimum elevation for fish passage is reasonable. The application of the HEC-RAS model to generate a wetted perimeter versus flow plot for each transect also is a justifiable scientific approach.

Cross-sectional surveys of instream and floodplain habitats were carried out at eighteen transects throughout the Upper Peace River basin. This is a valid technique to address the types of habitat that would be affected by increased base flows, higher water levels, and the role of medium and high flows for connectivity with wetland ecosystems. The cross-sectional data were entered into the HEC-RAS model to determine inundation characteristics for various habitats. This is a scientifically reasonable approach. A relatively complete set of 13 habitat types was mapped and GPS coordinates taken. Wetlands also were classified during the cross-sectional surveys. There does not seem to be an indication as to whether the wetland classification and characterization played any role in setting minimum flows and levels for the Upper Peace River.

The assumptions relevant to floodplain systems are stated clearly enough, and focus on addressing the overall management goal to "meet the hydrologic requirements of floodplain biological communities." The principal assumptions made are that the "riparian hardwood and cypress swamps" require seasonal flooding to maintain "biological integrity", and that the lower and upper floodplain zones require enough periodic sustained flooding to at least exclude upland vegetation. Specific comments on these assumptions are:

a. Maintenance of biological integrity in lower elevation swamps

Chapter 4 of the report provides some discussion of the concept of "biological integrity" that includes consideration of interactions between aquatic and terrestrial systems. These complex interactions are represented in the analysis by focusing on the life history requirements of selected amphibians (frogs and toads). To an extent, the use of anurans as surrogates for a broad suite of floodplain wildlife (and other aspects of "biological integrity") is reasonable, considering the limited charge to the District to use "available information" to guide the development of minimum flow recommendations. There is considerable merit in using these groups, as they represent a range of dependence on the presence of surface waters, from animals using temporary pools for reproduction (e.g. toads) to animals that are essentially aquatic and require permanent or near-permanent ponds or channel flow (e.g. bullfrogs). However, the focus on this range of habitat use was not carried through the analysis, which did not recognize that the temporary nature of some surface waters was as important as long-duration flooding in others. Also, in the future, we think more focus could be placed on other groups of animals, such as breeding birds and fishes that use off-channel habitats, even if only in terms of literature review and inference. Similarly, future studies should include more detailed discussions (literature-based) of other aspects of "biological integrity," such as nutrient interactions with aquatic systems.

b. Periodic sustained flooding is needed to maintain upper and lower floodplain vegetation

This assumption is reasonable, based on the body of published literature, which repeatedly focuses on flood frequency and duration as the principal determinants of floodplain vegetation characteristics. But, as this study demonstrates, even very careful hydrologic analyses spanning half a century or more of record is difficult to specifically relate to observed vegetation patterns in lowland forested systems.

> Floodplain forests simply do not respond in a dramatic fashion to reductions in flooding - woody species' dominance patterns change slowly, and respond to a variety of environmental factors besides flooding. Based on the soils and site information provided in the report, even invasion by upland species is unlikely to occur rapidly, and probably will never occur over large areas. It is clear that the upper and lower floodplain zones are complex systems that maintain hydric conditions in many areas due to precipitation storage and groundwater interactions in addition to the effects of flooding. Therefore, although the basic assumption reflects widely accepted ecological theory, in many ways it is too simplistic.

Thus, the assumptions upon which the riparian studies were based were probably too generalized, but they should not have been "eliminated" for that reason. Additional assumptions may have been appropriate, and probably should be incorporated into the design of any future studies of this type. Other analyses, discussed elsewhere in this review, would certainly be appropriate in the future, based on what was learned in this effort. However, they would not likely require "fewer assumptions." Rather, they would provide a more complete understanding of this complex system.

(c) Procedures and Analyses

The output from the HEC-RAS model and the field investigation at the 18 surveyed transects served as the basis for establishing recommended minimum flows and levels. Fish passage depths and wetted perimeter inflection point analysis were used to set minimum flows and levels. The report purposely focuses primarily on minimum flows and levels and recommendations at this time. We agree that this is a reasonable approach for this substantively degraded river ecosystem.

Minimum flows for fish passage are proposed to be set at 16 cubic feet per second (cfs) at Bartow, 27 cfs at Ft. Meade, and 45 cfs at Zolfo Springs. The report recommends that these minimum flows and levels be achieved at least 95% of the time annually. We believe these are scientifically reasonable target values with defensible justification to support of connection of currently isolated stretches of river and to promote fish passage.

Flows required to inundate transects to the surveyed “inflection” points provided similar values (17 cfs at Bartow, 26 cfs at Ft. Meade, and 26 cfs at Zolfo Springs). Based both on fish passage and wetted perimeter analyses, low minimum flows of 17 cfs at Bartow, 27 cfs at Ft. Meade, and 45 cfs at Zolfo Springs are recommended for exceedance 95% of the time annually. The data analyses support these recommendations made in the report.

Channel characteristics of the Upper Peace River establish a landscape setting for the determination of minimum flows and levels. Many of these features, however, remain disconnected, hydrologically, except under medium or high flows, which are not considered for recommendations within this report. Lateral and vertical habitat distributions were analyzed in detail with a particular emphasis on woody instream habitats. These habitats are particularly critical for aquatic invertebrates in lowland rivers and a focus on this habitat component is well justified. Inundation patterns for large woody debris and tree roots make good sense as attributes to consider when evaluating both minimum flows and levels and annual flow regime requirements.

The District report discusses the need for a range of flows for numerous biological requirements of river and riparian biota. No firm recommendations are made, but some guidelines are suggested for biofilm development, aquatic invertebrates, and amphibians. A similar hydrologic overview is presented for wetlands in the Upper Peace River corridor. Wetland classification and vegetation distributions are presented along with inundation patterns for many of the relict swamps and wetlands in the upper basin. Although useful in the context of establishing present conditions, these data do not play a significant role in the setting of minimum flow and level recommendations. In the Task 3 section, below, we discuss the alternatives that must be considered in order to incorporate support of other aquatic life uses to establishment of a minimum flow management strategy.

The use of floodplain habitats by wildlife focuses upon amphibians. The large number of vertebrate and invertebrate species that utilize the floodplain necessitates working with a subset of organisms. Amphibians were chosen for their potential value in assessing wetland conditions due to the variable hydrologic conditions required of different species. These inundation requirements for frog and toad breeding habitats make these species potentially valuable integrative indicators of present condition in the upper basin and possible indicators of improved conditions if inundation periods increase in the future in riverine wetlands within the Upper Peace River basin.

Minimum flows and water levels are proposed for adoption at the three USGS gages in the Upper Peace River basin. These flows and water levels are based on fish passage requirements and improved wetted perimeters based on surveyed geomorphic inflection points. The scientific analyses used to establish these recommended flows and levels are adequately described within the report and scientifically justifiable. Consideration of channel flow characteristics under these minimum discharge recommendations would be an additional factor worth evaluating, since support of both macroinvertebrate and vertebrate populations have been linked to these conditions (Statzner et al. 1988, Heede and Rinne 1990). The recommended minimum flows and water levels in this report, however, are based upon good hydrologic data, a well established modeling protocol, and detailed measurements of channel habitat at multiple locations. We concur that the recommended minimum flows and levels represent thorough scientific analyses of good quality historic and present data sets, and the recommendations are scientifically defensible and justifiable to meet the state management objectives.

Task 2: If a proposed method is not scientifically reasonable, the consultant shall address deficiencies and remedies.

Competent professionals conducted the data collection and analysis and we did not find any of the proposed methods to not be scientifically reasonable. The report provides a thorough review of basin characteristics, hydrology trends, water quality trends, ecological resources of concern, and key habitat indicators. The technical approach for determining minimum flows and levels included HEC-RAS modeling to determine fish passage depths and wetted perimeters, cross sectional surveys of instream and floodplain habitats, and analyses of inundation characteristics of instream and floodplain habitats as a function of discharge and water levels. These methods are scientifically reasonable and appropriate. Additional information on flow velocities associated with minimum flows and levels would enhance the overall analyses, but the proposed methods are appropriate for the task of establishing minimum flows and levels for the Upper Peace River to meet the stated management objectives.

Although they do not require remedy with respect to this report, some deficiencies in the evaluation of the riparian zones should be noted:

1. Combination of all vegetation data within a zone obscured any within-zone site variation.
2. Use of simple frequency as a descriptive statistic for vegetation obscured any dominance shifts that might be detectable.
3. Focus on anurans as surrogates for overall "biotic integrity" has some reasonable basis. However, the logic used in that analysis is difficult to follow. The report might also have benefited from more extensive discussions (based on literature) of other ecosystem functions that are dependant on interactions between the aquatic and floodplain systems.

As mentioned early, deficiencies in the vegetation studies do not require remedy with respect to this report. For reasons unrelated to the study results, the District is not recommending flow criteria relevant to vegetation maintenance. However, for future studies in this or other systems, a number of changes might be appropriate in the approach and analysis, and some of these are described in the Task 3 response, below. For the purposes of this report, however, the discussion presented in section 6.6.2 might be revisited to improve clarity. With regard to the discussion of minimum inundation criteria to support anuran populations, some additional explanation and clarification also is in order.

The deficiencies that require remedy for the purposes of this report involve some revision of the narrative and tables pertinent to vegetation data summarization and the discussion of anuran minimum-inundation requirements. The problems in the vegetation summary can be partly remedied by improving the tables, particularly Table 6-9, and more directly relating them to the points made in the discussion. Then, a more explicit discussion would be appropriate regarding how the vegetation data did or did not answer the fundamental questions posed by the study. Were any patterns detected of vegetation change relative to the hydrologic record? Why not?

Similarly, an expanded discussion would be appropriate regarding the logic behind adopting a 90-day, 3-year criterion for anuran habitat. The report (Section 6.7.1) states that "…the bullfrog is an indicator of healthy river hydroperiods…" yet the recommended minimum inundation period is far shorter than that presented as necessary to sustain bullfrog populations. This would seem to require further explanation, yet none is offered.

All of the deficiencies that are pertinent to the recommendations made in this report can be remedied with revisions of the text, as described above. There are also deficiencies in the basic study design which do not influence the recommendations made in this report, but should be addressed in any future studies of this nature. Specific suggestions for improving the study design are offered in the response in Task 3, below.

Task 3: If a given method for establishing minimum flows or levels is scientifically reasonable, but an alternative method is preferable, the reviewer shall list and describe the alternative scientifically reasonable method(s), and include a qualitative assessment of the effort required to collect data necessary for implementation of the alternative method(s).

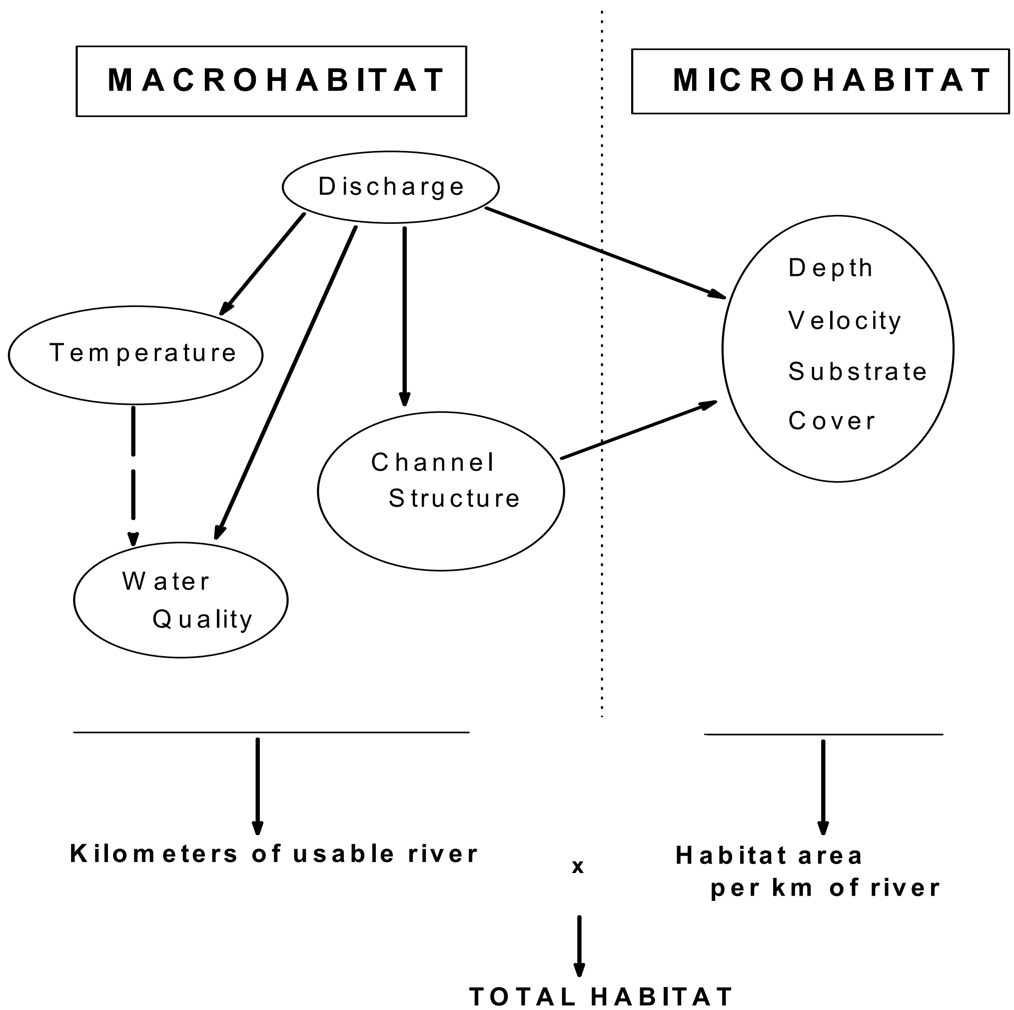
We believe that the methods used for establishing minimum flows and levels for the Upper Peace River are scientifically reasonable and an adequate *initial* step to creating a minimum-flow management strategy that will act to enhance a deteriorating river condition. The proposed MLFs are a good *first* step in the goal of rehabilitating the upper piece river. However, one additional analytical component could be added to the analysis and decision-making process for establishing flows and levels. This would be an analysis of how minimum flows and levels would impact flow conditions, that is, hydraulic habitat, in the river. As previously mentioned, certain fish and macroinvertebrate species, in particular, may require certain ranges of velocities or other complex hydraulics (as combinations of depth, velocity, and substrate; see Bovee 1986, Layzer and Madison 1995, and Gore *et al.* 2001) for successful reproduction, incubation, and sustained viability. A modeling study of flow velocities at various locations in the Upper Peace River coupled with field measurements under appropriate flow regimes would be a helpful addition to the otherwise thorough study used to determine minimum flows and levels.

The District has chosen to use the wetted perimeter technique, among the most popular techniques to attempt a combination of habitat data and hydrographic information (Nelson 1980, Gore and Mead 2002). It is generally assumed that providing and maintaining a wetted riffle promotes secondary production, fish passage and adequate spawning conditions. A modification of this approach is to select a set of cross-sections that represent the range of habitats available. A coefficient of the sensitivity to dewatering may also be applied to each cross-section. As might be expected, the shape of the cross-section of the channel has considerable influence on the ability of this method to be useful in making management decisions. Thus, the wetted perimeter technique is most useful at cross-sections that are wide, shallow and relatively rectangular. As cross-sectional geometry becomes more complex, the ability to detect a distinct MLF becomes more difficult. Indeed, the District report acknowledges that not all transects were able to demonstrate a distinct "break-point" where the wetter perimeter was complete.

Although the wetted perimeter technique has done an excellent job in predicting the wetted perimeter and levels necessary for fish passage, the stated management goals of the District report, we do not believe that these minimum flows will ultimately guarantee the ecological integrity of the upper Peace River. The *next* step in the rehabilitation of the upper Peace River will be to explore the relationship between hydraulic habitat at various discharges and the distribution of biota in the upper Peace River. Indeed, the data set already presented lacks only velocity measurements at intervals along each transect from being able to accomplish this sort of analysis. The Instream Flow Incremental Methodology (IFIM) (Bovee *et al.* 1998) and its software, the Physical Habitat Simulation (PHABSIM) require the type of data already acquired in the report plus the additional effort of determining the physical habitat requirements of target biota.

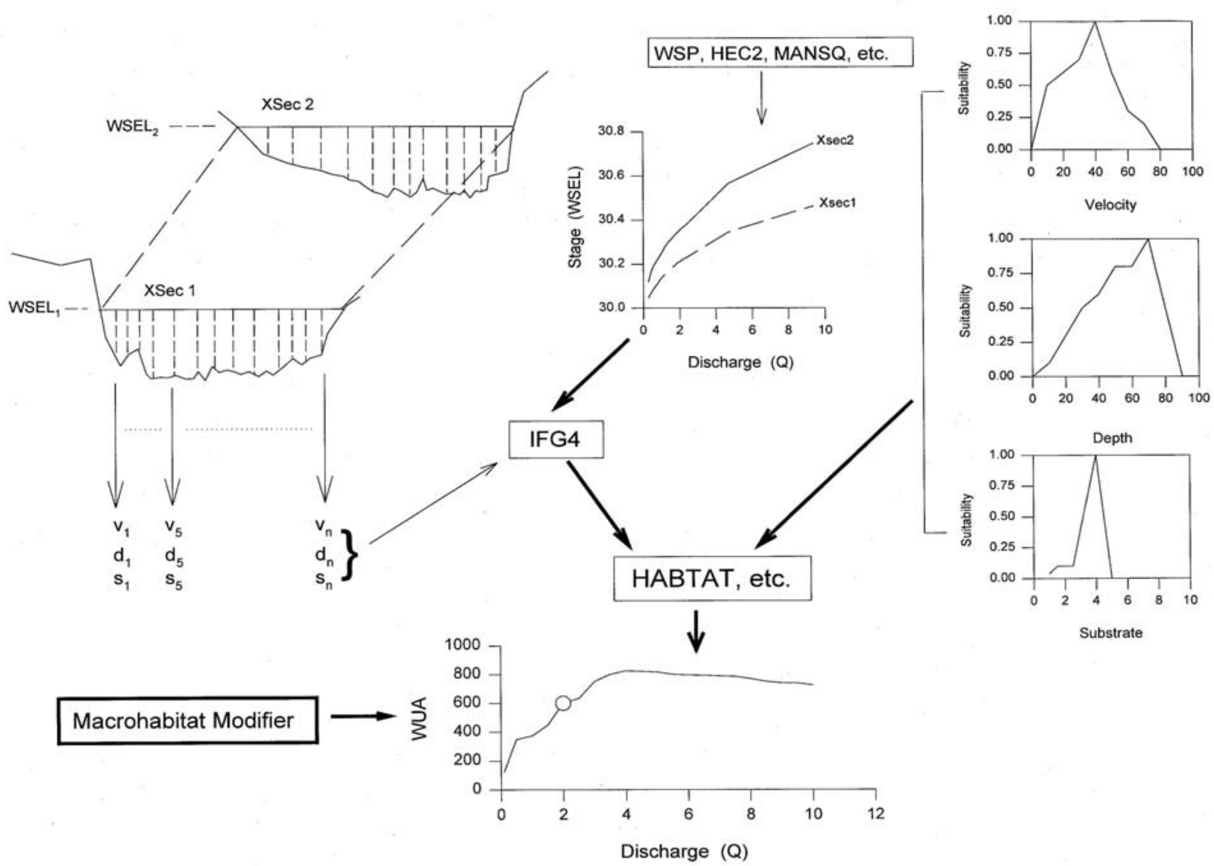
In general, there are five major hydraulic conditions that most affect the distribution and ecological success of lotic biota. These are suspended load, bedload movement, water column effects such as turbulence, velocity profile, and substratum interactions (near bed hydraulics). Singly, or in combination, the changes in these instream conditions can alter distribution of biota and disrupt community structure. Within a stream reach the interactions of these hydraulic conditions upon the morphology and behavior of the individual organisms govern the distribution of aquatic biota. IFIM attempts to describe these interactions in a relatively simple modeling technique.

IFIM and PHABSIM are often thought to be synonymous. In fact IFIM is a generic decision-making model that employs systems analysis techniques. IFIM guides stream managers in the process of choosing appropriate targets, endpoints, and data requirements to achieve the management goal. At one level or another, IFIM requires a substantive knowledge of how aquatic habitat value changes as a function of incremental changes in discharge. This knowledge must be employed *a priori*, during the negotiation phases of the decision-making process. Replicate habitat sampling, biological sampling for the development of habitat suitability curves, sediment and water routing studies, as well as physical habitat, temperature, and water quality simulations may be necessary to properly depict the condition of the catchment under new operating scenarios (Sale 1985). In IFIM, habitat suitability is treated as both *macrohabitat* and *microhabitat*. Macrohabitat suitability is predicted by measurement and/or simulation of changes in water quality, channel morphology, temperature, and discharge along the length of the managed reach. Much of these data requirements has already been collected and reported in the current District study. These conditions may have an overriding impact upon decisions made at the microhabitat level. Microhabitat suitability consists of individual species' preferences for these same criteria, reflected as depth, velocity, substrate or channel condition, and cover. Those individual preferences are incorporated into PHABSIM to obtain predictions of changes in available habitat at a selection of stream segments, "typical" of the reach being managed. In combination, microhabitat and mesohabitat provide the information necessary to adequately determine management alternatives.



[Adapted from Stalnaker *et al.* 1995, Gore and Mead 2002]

The microhabitat evaluation within the IFIM methodology is completed through PHABSIM. Through a series of subroutines programs contained within PHABSIM, a prediction of the amount of available habitat (as weighted usable area, WUA) for a target organism over a range of discharges is created. HABTAT and its associate programs requires hydrologic information in the form of transect (cell-by-cell) information on depth, velocity, cover value and/or substrate composition) and biological information in the form of preferences or suitabilities for these conditions by the target organism. Where possible, the hydraulic information for each transect should be measured. However, there are several "desk-top" simulations that can also simulate these data when field measurements are not available or impossible to measure (in the case of very large rivers or those with rapidly varying, unsteady flow). In addition to simulations within PHABSIM (routines such as WSP, MANSQ, and IFG4), other hydraulic simulations are frequently used. These include steady-state models such as HEC-2 (USACE 1982) and dynamic flow models such as RIV1H and BIRM (Johnson, 1982,1983). Regardless of how the hydraulic information is provided to PHABSIM, stage-discharge relationships are provided to the hydrologic simulation (usually IFG4) that predicts changes in velocity, cell-by-cell, with changes in water surface elevation. This prediction is accomplished through a series of back-step calculations through Manning's equation or, at the option of the user, Chezy's equation. This assumption assumes that substrate or channel geometry will remain stable over the range of discharges to be simulated. As an alternative, Jowett (1998) has suggested that on-site measurement of changes in hydraulic geometry provide estimates comparable to the back-step predictions contained within IFG4.



[Schematic of the PHABSIM model. The circle on the WUA/Discharge plot (above) represents the discharge at which 15% of habitat is lost]

Thus, the PHABSIM model, in its current form, represents, at best, a quasi-two-dimensional model, since it distributes velocities and discharges laterally along each transect. Cell-by-cell evaluations of weighted usable area (the product of preference criteria for each of the hydraulic conditions simulated and the total surface area of each cell) are computed through HABTAT and related subroutines. Although the WUA/Discharge relationship can provide information on the potential gains and losses of habitat with changes in discharge and can provide information on the apparent optimum and minimum flows, the output of PHABSIM is often not the product from which flow decisions are made. It will still be necessary to determine the relationship between optimum and minimum flows and their duration during wet and dry conditions. That is, the decision-makers must decide what percentage of the time a selected flow is met or exceeded during an average hydrographic and during unusually wet or dry years. This is accomplished through the Habitat Time Series (HTS) component of IFIM (Milhous *et al.* 1990). Such conditions as median habitat value over ten or twenty years of record, the percentage of available habitat if certain magnitudes of flood were attenuated or enhanced, and the duration of low habitat conditions are typical predictions of a HTS evaluation. Decisions are usually based upon an established goal (most often, no greater than a 15% loss of available habitat).

Traditionally, the IFIM technique has focused on habitat availability of target fish species. Gore and Nestler (1988) believe that habitat suitability curves can be thought of surrogates for basic niche. That is, the derived suitability curves reflect maximized density when preferences approach unity. This should not, however, be interpreted as the equivalent of the carrying capacity of the system. The conversion to WUA is an attempt not to predict density changes, but changes in relative habitat quality and availability.

Habitat suitability information can come from a variety of sources. Most frequently, resource managers use published suitability curve information (the so-called "Blue Book" series published by the U.S. Fish and Wildlife Service). However, on-site development of habitat suitability criteria often produces the most accurate predictions (Bovee 1986). Among fish species, habitat suitability is most often generated for spawning, incubation, fry, juveniles and adult stages. Frequently, when several life stages are involved, several different release scenarios must then be considered to assure the success of all life stages. In salmonid streams, this type of evaluation is relatively simple. However, as the number of species of concern increases, the decision-process to provide adequate releases to support all species and life stages becomes quite complex. Competitive interactions between species assemblages can result in significantly different species preferences among several streams in the same catchment (Freeman *et al.* 1997); thus, making transferability of standard curves impossible. In warmwater streams, where fish communities can be dominated by a variety of species using distinctly disparate habitats, Leonard and Orth (1988) have suggested that "habitat guilds" are more appropriate than individual life stages or species-specific habitat suitability criteria. These kinds of compromises support Gore and Nestler's conclusion that the appropriate use of IFIM, in its current composition, is as a predictor of habitat quality rather than as some surrogate of density or productivity.

The instream flow requirements for benthic macroinvertebrates received equal attention during the development of IFIM (Gore and Judy 1981). However, most stream managers have largely discounted these considerations because of perceived difficulties in collection (large sample size), taxonomic identification and habitat suitability curve generation, as well as inability to assign "benefit" to the maintenance of benthic communities. Instead, many regulatory agencies and managers have concluded that enough flow for target fish species (and their individual life stages) is also sufficient for benthic species. Only recently have benthic macroinvertebrate habitat conditions become a frequent component of IFIM analysis. These application have been quite generic, based upon curves created from literature surveys (the *Delphi* approach, Bovee 1986) or broadly-defined curves (at the ordinal level; Peters *et al.* 1989). However, Statzner *et al.* (1988) and Gore and Bryant (1990) have demonstrated that different macroinvertebrate life stages require different hydraulic conditions to achieve completion of life cycles, just as fish species have very different spawning, incubation, and maintenance requirements. Most recently, Gore *et al.* (2001) demonstrated that inclusion of macroinvertebrate criteria often dramatically alter decisions on flow reservations when previously made, based upon fish species alone.

The level at which the District may want to employ such a modeling system will vary with the management goals. The table below (adapted from Gore and Mead 2002) suggests the possibilities.

Target for Evaluation	**Type of Model**
Longitudinal Succession	One-dimensional macrohabitat models – temperature, dissolved oxygen, other dissolved chemicals. Evaluate: degree-day accumulations of temperature, thresholds of tolerance, and extent of available acceptable conditions.
Habitat segregation or patchiness	Two-dimensional microhabitat models – depth/velocity or complex hydraulics (especially shear for mussels) in association with substrate materials and cover in small streams.
Variable meteorological processes	Time-series analysis: total amount of usable habitat in the aggregate over the stream network. Evaluate seasonal occurrence and duration of ecological bottlenecks associated with flood, drought, or human created water demands.

IFIM procedures and PHABSIM software are widely known and easily accessible through Internet links to the USGS Midcontinent Ecological Science Center (http://www.mesc.usgs.gov/). Since the District has already surveyed a comprehensive set of transects for this study, it would be a relatively easy task to revisit those same transects and to record changes in velocity distribution and substrate/cover characteristics at regular intervals along each transect. These data, combined with stage/discharge relationships for each transect provide the calibration data for PHABSIM. The most time-consuming and labor intensive portion of the process would be in the acquisition, more likely development, of habitat suitability criteria for target fish species of concern in the upper Peace River. Only a relatively few species (Florida gar, bluegill, largemouth bass, black crappie, gizzard shad, golden shiner, threadfin shad, brown bullhead, and channel catfish) are currently available. However, the acquisition of field data to create the habitat suitability criteria is fairly easily accomplished within a few months time. Macroinvertebrate criteria are currently available (Gore *et al.* 2002) and the USGS have "Blue Book" criteria for recreational boating (canoeing and kayaking, for example) as another management tool for use in the IFIM process.

We suggest, then, that, in its planning process for further rehabilitation and management of the upper Peace River, the District consider IFIM procedures which link hydraulic habitat of target biota to the already obtained hydrological and physical data described in this report.

Regarding the evaluation of riparian wetlands, we recommend a set of specific changes for any future studies of floodplain systems, either in the Upper Peace River or in similar stream systems. These are based on the lessons learned in the Upper Peace so far, as well as other work in lowland forest systems of the southeastern United States.

1. The historic hydrologic analysis, establishment procedures for transects, and designation of major ecological zones should all be retained and used for additional studies if possible. However, additional work should be done to recognize fairly subtle subdivisions within those zones, particularly in terms of geomorphic settings that differentially influence ponding and soil moisture conditions. The data provided for review clearly indicate that, within a single transect segment (zone), there is considerable variation in drainage conditions. It seems likely that there are many sites that are strongly influenced by precipitation storage and shallow subsurface flows, and these factors can easily mask any changes in seasonal stream overflow patterns. For example, the allusion to certain areas as "flatwoods" and the identification of hydric soils in the highest floodplain zone tend to support this view of precipitation storage and soil saturation as an important factor in determining overstory composition. Similarly, the distribution of species like *Carya aquatica* across all zones suggests that small depressions are present throughout the system. National Wetland Inventory mapping rarely is sufficient to detect such microsite variation - it must be recognized and classified in the field (though soil survey mapping is sometimes sufficient). However, by combining all vegetation into a single belt transect "plot," this study assured that minor site variation within each zone was not detected by the field studies. The use of frequency of occurrence as the principal descriptor of vegetation further

blurred differences between and within zones. The discussion indicates that there are strong dominance tendencies associated with each zone, easily recognizable in the field, but these cannot be described adequately unless the samples are stratified by drainage, soils, and/or geomorphic setting, and the sample data are summarized quantitatively (e.g., using relative dominance based on basal area).

2. One of the basic purposes of this effort was to detect changes in composition that could be related to the documented changes in hydrology over time. This was an ambitious goal, and it is one that is difficult to address in most lowland forest systems. In fact, we are aware of no studies that could demonstrate specific and clear effects of altered hydrology on southeastern lowland forest composition and structure, except in cases of distinct increases in water levels, or in communities at the extreme ends of the hydrologic gradient (e.g. baldcypress stands along lakeshores). However, given the carefully reconstructed hydrologic record for the study sites used in this project, it may be possible to detect such changes if the vegetation sample sites are stratified as described above. Seedling and sapling composition can then be examined within a subset of those samples where forest openings have occurred within the period of the hydrologic record. This will reduce or eliminate the influence of shading on seedling survival, and may produce a clearer picture of any trends toward a shift to a "drier" forest within a zone. However, this approach definitely requires that site variation due to ponding and interflow be accounted for.

3. Recognition of site variation and the importance of internal water storage and movement in maintaining plant communities produces a different conceptual model of ecosystem processes than the one that guided this study. Rather than focusing exclusively on flooding as a control on riparian characteristics and functions, the system might better be conceived as a series of terraces (rather than floodplain zones), each of which has and will retain unique wetland characteristics regardless of flooding regimes. In that sense, they function as part of the river corridor even if direct interactions with the aquatic system have been reduced. The unique functions and processes that occur on these sites, both flood-related and otherwise, should receive attention as part of the overall resource management and recovery program.

4. Regardless of the effects on plant communities, changes in flooding will certainly have significant effects on a variety of other ecological interactions. Even without additional field studies, there is ample ecological literature to support a thoughtful assessment of the likely effects of altered hydrology on stream-floodplain interactions (nutrient exchange, use of floodplain sites by aquatic species, etc.). Similarly, terrestrial wildlife use of the riparian area can be evaluated in considerable detail simply from life history requirements, as was done for the assessment of probable anuran responses in the draft report. The feeding habitat needs of various waterfowl, for example, can be considered in

terms of the availability and timing of water bodies of various depths. The analysis of amphibian habitat used in the report (keying on duration of inundation) can be complemented by an assessment of the presence of temporary (usually precipitation- or ground-water-based) pools, which are important to many amphibians due to the absence of fish predators. Spatial and temporal considerations also can be brought into play in developing adaptive management approaches for systems such as the Upper Peace. For example, nesting by colonial waterbirds may require that stands of particular tree species be available, and that those stands be of sufficient size, and contain trees of sufficient stature, to support nesting by the target species. Under natural conditions, such stands may have been initiated at regular intervals by channel migration and the creation of new substrates, followed by colonization by pioneer species that would form even-aged stands in patches throughout the system. Under modern conditions, providing such habitats may require more active intervention, such as planning for periodic regeneration of large stands of trees in sites scattered throughout the riparian corridor. It may also require that those target sites be isolated from human disturbance. Similar management strategies can be developed to address neotropical migrants, small mammals such as bats, and a wide variety of other species. The point is, ecological management of a river corridor in the modern, developed environment should focus on potential restoration and management actions beyond recovery of minimum flow levels, or even flow regimes. Whatever the flooding regime that can be established and maintained, there must be a healthy riparian system interacting with it if full ecological benefit is to be realized. This in turn must be based on the recognition that some processes that once operated in these systems have not been lost, while others cannot be fully recovered - they must be replaced either with direct management, or new models of ecosystem function should be adopted that reflect the reality of the altered environment. Taking such an approach will allow limited resources to be applied where they can do the most good, rather than being expended trying to recover an unrecoverable condition.

As previously mentioned, one of the weaknesses of the District report is the ability to link maintenance of medium and high flows to maintenance of riparian floodplains. This linkage is a critical component for the maintenance of the integrity of the Upper Peace River catchment. We suggest that the ultimate goal for restoration of that integrity will necessarily be the recreation of that medium and high flows that establish these linkages. Regardless of the final management decisions and modeling techniques chosen by the district to achieve this goal, there is a number of so-called building block models to provide a way to more closely mirror original hydrologic and hydroperiodic conditions within the basin.

The assumptions behind *building block* techniques are based upon simple ecological theory; that organisms and communities occupying that river have evolved and adapted their life cycles to flow conditions over a long period of pre-development history (Stanford *et al.* 1996). Thus, with limited biological knowledge of flow requirements, the best alternative is to recreate the hydrographic conditions under which communities had existed prior to disturbance of the flow regime.

The most simple of these allocations models was proposed by Bovee (1982) who recommended that a surrogate of the natural annual pattern of stream flows could be approached by allocating the median (exceeded 50% of the time) monthly flow. Again, this technique requires an extended period of undisturbed flow records or the ability to reconstruct these records.

There is a wealth of research to indicate that hydrological variability is the critical template for maintaining ecosystem integrity. The use of this natural variability as a guide for ecosystem management has been widely advocated in the past decade. Thus, even the simplest of monthly allocations based upon some sort of restoration of a natural hydrograph are preferred to a standard allocation. Although variability is a key to ecosystem maintenance, some sort of predictability of variation must be maintained. It must be realized that survival of aquatic communities is contained within the envelope of that natural variability (Resh *et al*. 1988). Thus, the simplest of the building block models may not include sufficient variability. In addition to the seasonal pattern of flow, such conditions as time, duration and intensity of extreme events, as well as the frequency and predictability of droughts and floods may also be significant environmental cues. Also, the frequency, duration, and intensity of higher and lower flows can affect channel morphology and riparian vegetation, and thus change aquatic habitat. Indeed, the rate of change of these conditions must also be considered (Poff and Ward 1989, Davies *et al*. 1994, Richter *et al*. 1996).

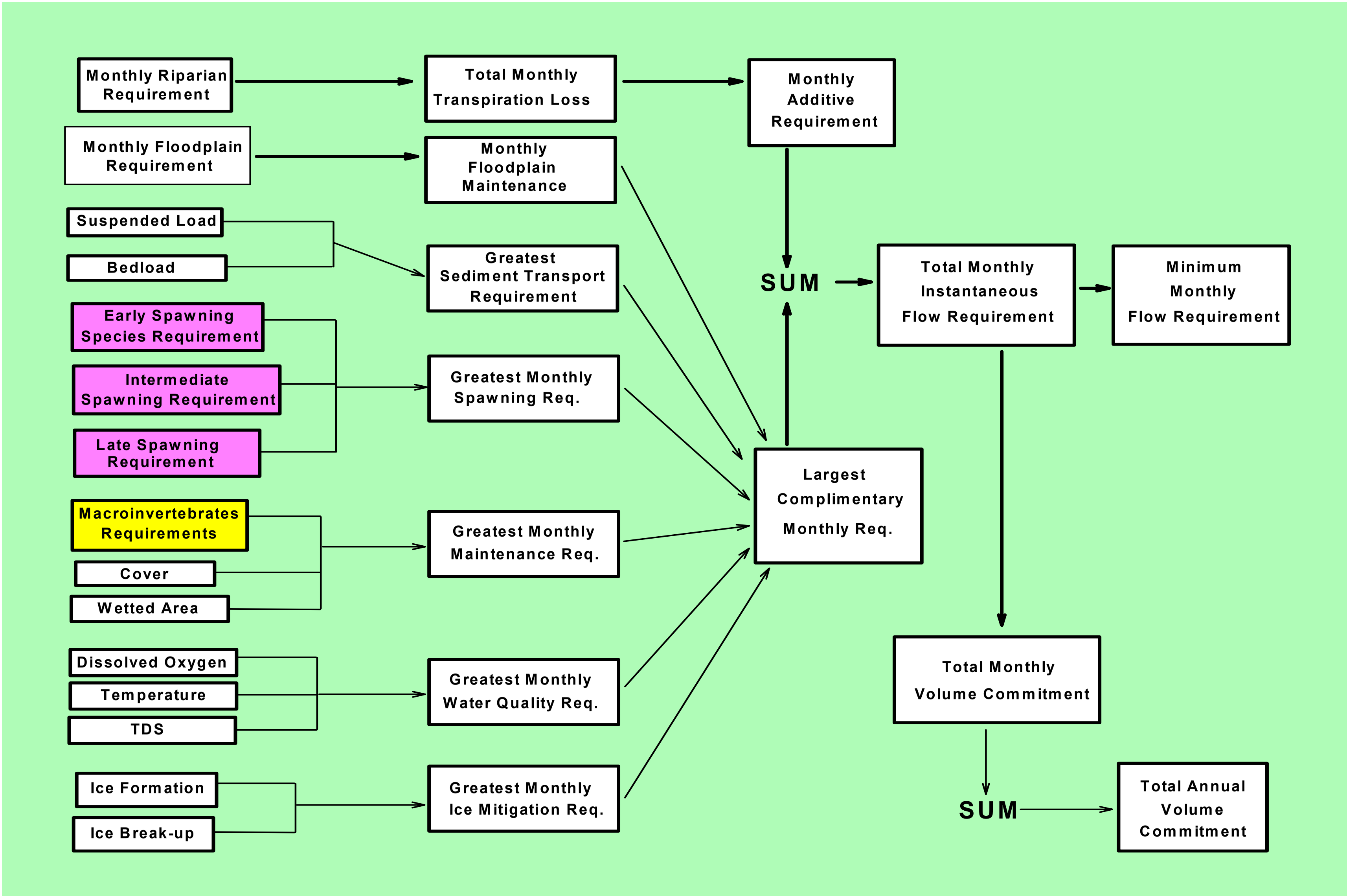
In order to include conditions that reflect greater variability yet maintain some of the natural predictability, Arthington *et al*. (1991) proposed a method which draws upon features of the daily flow record for flow allocations in dryland regions such as Australia and South Africa. Four attributes of the natural flow record are analyzed: low flows (based upon an arbitrary exceedance interval), the first major wet-season flood, "medium-sized" flood events, and "very large" floods over a period of record (usually 10 to 20 years). These are progressively summed (as "building blocks") to recommend a modified flow regime that provides predictable variability in duration, intensity and frequency of flood and drought events.

Richter *et al*. (1996, 1997) have suggested a more sophisticated "building-block" model, termed the "Range of Variability Approach (RVA). This approach is specifically designed as an *initial, interim* river management strategy that attempts to reconstruct the natural hydrograph. By a statistical examination of thirty-two hydrological parameters most likely to change ecological conditions, the RVA establishes management targets for each of these characteristics and then proceeds to establish a negotiation session in which a set of guidelines are established to attain these flow conditions. This analysis requires that greater than twenty years of daily streamflow records be available for this analysis. The RVA requires that, during each subsequent year, the hydrograph created by RVA be compared to the target streamflows and new management strategies be created to more closely match the RVA. This process of revisiting the management strategy allows ongoing ecological research to contribute new information that may result in the change of RVA targets. These iterations continue until the management targets are achieved.

The building-block models are the "first-best-approximation" of adequate conditions to meet ecological needs. More often than not, resource agencies have kept hydrographic records for long periods of time when little or no biological data have been maintained. Even when poor hydrographic records have been collected (or for less than ten consecutive years, Larson (1981) suggested that a surrogate indicator for minimum flows could be assigned as 0.0055 m^3/s for each square kilometer of drainage area during dry months with adjustments for spawning flows.

Hydrographic and "building-block" models have the advantage of being easy to explain to the public and decision-makers and, because they are rapid and less time consuming, are frequently chosen to make water resource management decisions. The greatest potential misuse of the building block models, as in any ecohydrological model, is the institutional assumption that the first answer from a model is the *only* answer necessary to make adequate management decisions. That is, there is a tendency in regulatory agencies to make long-term management decisions from the first set of output data provided by the model. It is almost always the case that the first iterations of any model are based on the smallest amount of calibration information. With the building block models lacking any ecological information, it can be quite dangerous to make long-term decisions on the first output from these models. There are no assurances that the goal for the reservation will be met. Indeed, the "resource" goal may not have been correctly identified. Yet, it often occurs that "permits" to utilize the resource are issued for a period of five or more years; thus, reevaluation of the strategy can only occur at those intervals. However, as suggested by Richter *et al.* (1977), these management strategies must be revisited on an annual basis and modified, as ecological research determines more accurate information on flow requirements to sustain ecological processes. This process is in significant conflict with the resource user who prefers a known release schedule for as many years in advance as possible in order to make sound business decisions about supply to customers. This is a conflict that still must be addressed by the users of all of the models.

Although it is rarely used in such a manner, the IFIM procedure is ideal for a building-block approach to restoring or mimic hydrographic variation. For example, in some of the earliest work on the development of IFIM, Bovee *et al*. (1978) suggested combining IFIM results with other models to create just such a set of building blocks to provide minimum monthly flow requirements which are combined to produce a manageable annual hydrograph and a total annual volume commitment (see diagram below).


Monthly Riparian Requirement
Monthly Floodplain Requirement
Suspended Load
Bedload
Early Spawning Species Requirement
Intermediate Spawning Requirement
Late Spawning Requirement
Macroinvertebrates Requirements
Cover
Wetted Area
Dissolved Oxygen
Temperature
TDS
Ice Formation
Ice Break-up
Total Monthly Transpiration Loss
Monthly Floodplain Maintenance
Greatest Sediment Transport Requirement
Greatest Monthly Spawning Req.
Greatest Monthly Maintenance Req.
Greatest Monthly Water Quality Req.
Greatest Monthly Ice Mitigation Req.
Monthly Additive Requirement
SUM
Largest Complimentary Monthly Req.
Total Monthly Instantaneous Flow Requirement
Minimum Monthly Flow Requirement
Total Monthly Volume Commitment
SUM
Total Annual Volume Commitment

Current stream managers do utilize PHABSIM results to allocate different monthly discharges during the year. However, the focus remains upon the hydrological needs to maintain the biotic component of the system. However, it is quite apparent that such phenomena as floodplain maintenance and water quality are also ecological integrity issues linked to maintenance of a certain hydrograph. In that respect, building-block models probably provide better management of the physical integrity of catchment ecosystems. These models, then, by combining a more complete model of hydrological change within the fluvial corridor with a sophisticated model of ecosystem response to these flow changes, could be used to assess not only restoration potential, but the vulnerability of these systems to continued disturbance from catchment alteration.

Finally, these building blocks can be used to make sound management decisions about the future integrity of the river ecosystem. Cardwell *et al.* (1996) have suggested an optimization model as a planning tool that combines both the size and frequency of water shortages with habitat requirements to suggest appropriate water management schemes. Indeed, Cardwell *et al.* suggest that if we can express political, economic or other social concerns as a linear combination of storage, release, and or diversion in a given time period, these can be used as additional constraints in the model. Such integrated approaches that link theoretical models, ecological phenomena, and institutional concerns, will be the next great step in better allocating water of the Upper Peace River catchment to the demands of the residents of the District while maintaining the integrity of the riverine ecosystem.

3.0 REFERENCES

Arthington, A.H., J.M. King, J.H. O'Keeffe, S.E. Bunn, J.A. Day, B.J. Pusey, D.R. Bluhdorn, and R. Tharme. 1991. Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems. Pp. 69-76 *in*: J.J. Pigram and B.P. Hopper (eds.) *Water Allocation for the Environment: Proceedings of an International Seminar and Workshop*, The Centre for Water Policy Research, Univ. of New England, Armidale, New South Wales, Australia.

Bovee, K.D. 1982. *A guide to stream habitat analysis using the instream flow incremental methodology.* Instream Flow Info. Paper 12, U.S. Fish and Wildlife Service, FWS/OBS-82/26.

Bovee, K.D. 1986. *Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology.* Instream Flow Info. Paper 21, U.S. Fish and Wildlife Service, Biol Rep. 86(7).

Bovee, K.D., J.A. Gore, and A.J. Silverman. 1978. Field testing and adaptation of a methodology to measure "in-stream" values in the Tongue River, Northern Great Plains (NGP) region. U.S. Environmental Protection Agency, EPA-908/4/78-004A.

Bovee, K.D., B.L. Lamb, J.M. Bartholow, C.B. Stalnaker, J. Taylor, and J. Henriksen. 1998. *Stream habitat analysis using the instream flow incremental methodology.* U.S. Geological Survey, Biol. Res. Div., Info. and Tech. Rpt. USGS/BRD-1998-004.

Cardwell, H.I. Jager, and M.J. Sale. 1996. Designing instream flows to satisfy and human water needs. *Journal of Water Resources Planning and Management* 122: 356-363.

Davies, B.R., M.C. Thoms, K.F. Walker, J.H. O'Keeffe, and J.A. Gore. 1994. Dryland rivers: their ecology, conservation, and management. Pp. 484-511 *in:* P. Calow and G.E. Petts (eds.) *The Rivers Handbook. Volume 2.* Blackwell Sci. Publ., London.

Freeman, M.C., Z.H. Bowen, and J.H. Crance. 1997. Transferability of habitat suitability criteria for fishes in warmwater streams. *North American Journal of Fisheries Management* 17: 20-31.

Gore, J.A., and R.M. Bryant, Jr. 1990. Temporal shifts in physical habitat of the crayfish, *Orconectes neglectus* (Faxon). *Hydrobiologia* 199: 131-142.

Gore, J.A., and R.D. Judy, Jr. 1981. Predictive models of benthic macroinvertebrate density for use in instream flow studies and regulated flow management. *Canadian Journal of Fisheries and Aquatic Science* 38: 1363-1370.

Gore, J.A., J.B. Layzer, and J. Mead. 2001. Macroinvertebrate instream flow studies after 20 years: a role in stream and river restoration. *Regulated Rivers* 17: 527-542.

Gore, J.A., and J. Mead. 2002. The Benefits and Dangers of Ecohydrological Models to Water Resource Management Decisions. *In: Ecohydrology: A new Paradigm* United Nations/UNESCO, Geneva and Cambridge University Press.

Gore, J.A., and J.M. Nestler. 1988. Instream flow studies in perspective. *Regulated Rivers* 2: 93-101.

Heede, B.H., and J.M. Rinne. 1990. Hydrodynamic and fluvial morphologic processes: implications for fisheries management and research. *North American Journal of Fisheries Management* 10: 249-268.

Johnson, B.H. 1982. *Development of a Numerical Modeling Capability for the Computation of Unsteady Flow on the Ohio River and its Major Tributaries.* Tech. Rpt. H-82-20, USACE, Waterways Exp. Stn, Vicksburg, MS.

Johnson, B.H. 1983. *Users Guide for Branched Implicit River Model (BIRM) with Application to the Lower Mississippi River.* Hydraulics Lab., USACE, Waterways Exp. Stn., Vicksburg, MS.

Jowett, I.G. 1998. Hydraulic geometry of New Zealand rivers and its use as a preliminary method of habitat assessment. *Regulated Rivers* 14: 451-466.

Larson, H.N. 1981. *New England Flow Policy*. Memorandum, interim regional policy for New England stream flow recommendations, U.S. Fish and Wildlife Service, Region 5, Boston, MA.

Layzer, J.B., and L.M. Madison. 1995. Microhabitat use by freshwater mussels and recommendations for determining their instream flow needs. *Regulated Rivers* 10: 329-345.

Leonard, P.M., and D.J. Orth. 1988. Use of habitat guilds to determine instream flow requirements. *North American Journal of Fisheries Management* 8: 399-409.

Milhous, R.T., J.M. Bartholow, M.A. Updike, and A.R. Moos. 1990. *Reference manual for generation and analysis of habitat time series - Version II.* U.S. Fish and Wildlife Service, Biol. Rpt. 90(16).

Peters, E.J., R.S. Holland, M.A. Callam, and D.L. Bunnell. 1989. Platte River suitability criteria … habitat utilization, preference and suitability index criteria for fish and aquatic invertebrates of the lower Platte River. *Nebraska Technical Series No. 17*, Nebraska Game and Parks Commission, Lincoln, NB.

Poff, N.L., and J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. *Canadian Journal of Fisheries and Aquatic Science* 46: 1805-1818.

Resh, V.H., A.V. Brown, A.P. Covich, M.E. Gurtz, H.W. Li, G.W. Minshall, S.R. Reice, A.L. Sheldon, J.B. Wallace, and R. Wissmar. 1988. The role of disturbance in stream ecology. *Journal of the North American Benthological Society* 7: 433-455.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. *Conservation Biology* 10: 1163-1174.

Richter, B.D., J.V. Baumgartner, R. Wiggington, and D.P. Braun. 1997. How much water does a river need? *Freshwater Biology* 37: 231-249.

Sale, M.J. 1985. Aquatic ecosystem response to flow modification: an overview of the issues. Pp. 22-31 *in*: F.W. Olson, R.G. White, and R.H. Hamre (eds.) *Proceedings of the Symposium on Small Hydropower and Fisheries*. American Fisheries Society, Bethesda, MD.

Stalnaker, C., B.L. Lamb, J. Henrikson, K. Bovee, and J. Bartholow. 1995. *The Instream Flow Incremental Methodology. A Primer for IFIM.* Biol. Rpt. 29, National Biological Service, Washington, DC.

Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. *Regulated Rivers* 12: 391-413.

Statzner, B., J.A. Gore, and V.H. Resh. 1988. Hydraulic stream ecology: observed patterns and potential applications. *Journal of the North American Benthological Society* 7: 307-360.

USACE (U.S. Army Corps of Engineers). 1982. *HEC-2, Water Surface Profile; Users Manual*. Computer Program 723-X6-L202A, USACE-HEC, Davis, CA.

White, W.A. 1970. The geomorphology of the Florida Peninsula. Florida Bureau of Geology, Bulletin No. 51.