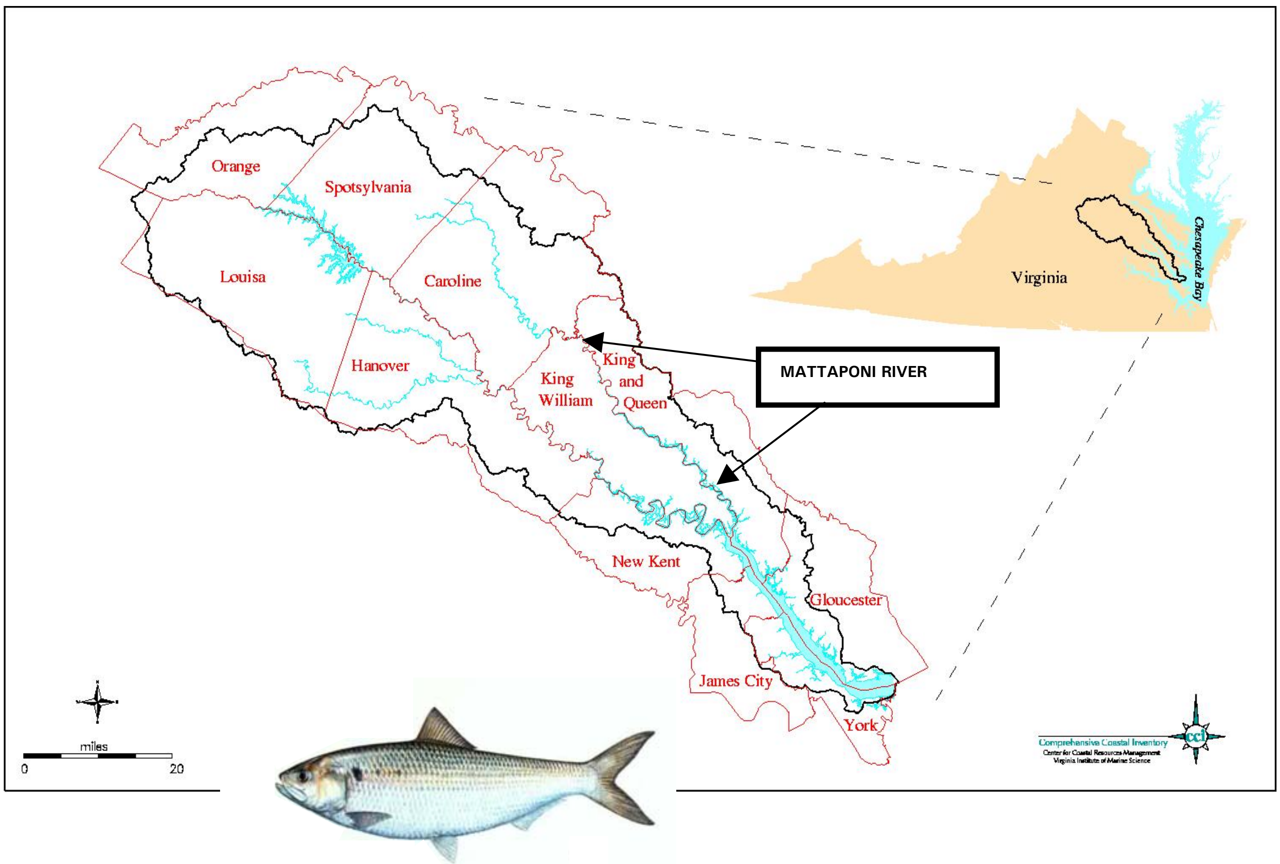
KING WILLIAM RESERVOIR – MATTAPONI RIVER FISH IMPACT ASSESSMENT AND MITIGATION REPORT



Versar INC.

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KING WILLIAM RESERVOIR - MATTAPONI RIVER FISHERIES IMPACT ASSESSMENT AND MITIGATION REPORT

Prepared for:

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c/o Office of City Manager
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King William Reservoir Fisheries Panel

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April 1, 2004

EXECUTIVE SUMMARY

The potential impacts of the proposed King William Reservoir (KWR) intake on fish populations in the Mattaponi River has been a subject of extensive debate for many years. Over this period of time, stakeholders have offered conflicting opinions on and assessments of those impacts in a number of federal and state forums. The Regional Raw Water Supply Study Group (RRWSG) formed the King William Reservoir Fisheries Panel to conduct an objective and comprehensive review of fish impact issues and develop recommendations that would address the issues identified. This report presents the findings and conclusions of the Panel.

What is the King William Reservoir Fisheries Panel?

The Panel is a group of seven fisheries scientists assembled by the RRWSG who offer demonstrated expertise in all aspects of fish impact assessment and project design and operations that might affect Mattaponi River fish populations, including: wedgewire screen technology and effectiveness of various water intake screening technologies for fish protection, water withdrawal effects on anadromous fish populations and monitoring and mitigating those effects; monitoring and assessment of Virginia riverine anadromous and resident fish communities; American shad and river herring life history and biology; estuarine and anadromous fish monitoring; fish impact assessment and fisheries management; and fish population and impact assessment modeling.

What was the function of the Panel?

The Panel was instructed by the RRWSG to evaluate the potential for the KWR intake to impact Mattaponi River American shad population and other fish species and to provide recommendations on monitoring, operation and mitigation that would ensure that there would be virtually no impact of KWR water withdrawal on the shad population and minimal impacts on other important Mattaponi anadromous and resident fish species.

What was the scope of the Panel's efforts?

The Panel evaluated the potential for impact to Mattaponi River fish species from an intake to be located at Scotland Landing, with intake screens designed as currently proposed for the KWR and operated under the terms of the existing Water Protection Permit from the Virginia Department of Environmental Quality (VDEQ). The project as now proposed employs a pumping hiatus during the American shad spawning period (with the hiatus developed by the Panel) that would be implemented in years of normal operation. The prior KWR project proposal did not include such a hiatus. The RRWSG indicated to the Panel that the project as proposed calls for suspension of the hiatus in years when a drought emergency is declared by the State of Virginia in order to meet projected water supply requirements. Thus, the Panel was required to address potential impacts to fish from spring withdrawals during drought emergency years. The Panel was not asked to address and did not consider any other impacts of the KWR, any alternative intake locations, or any impacts from elements of the project other than the Mattaponi River intake.

How did the Panel operate and how did they interact with RRWSG representatives and other stakeholders?

The Panel conducted their evaluations and deliberations via e-mail, conference calls and meetings. Representatives of RRWSG's engineering contractor, Malcolm Pirnie, and of the City of Newport News, on behalf of the RRWSG, participated at various times in Panel deliberations and meetings. These representatives responded to Panel questions and requests for information, and also raised questions and offered suggestions regarding draft material provided by the Panel over the course of this effort. However, in no instance was the Panel directed by RRWSG representatives to alter or modify any finding or conclusion. A working draft of this report was provided to the Virginia Marine Resources Commission (VMRC) staff and its technical consultant, Virginia Institute of Marine Science (VIMS) on March 5 and the Panel met with VMRC and VIMS staff on March 19 to discuss findings presented in the draft report and identify issues that both staffs recommended be addressed in the final report.

What information was provided to and used by the Panel in their assessments and deliberations?

The RRWSG made available to the Panel all documents in the existing KWR permitting record relating to fish impacts, including the comprehensive assessments by VIMS and ASA (Mann 2003; ASA 2003). The Panel also drew upon each Panel member's literature information sources as appropriate to the topic being addressed. In particular, extensive ichthyoplankton data from a 30-year monitoring program in the Hudson River was used to investigate potential temperature triggers for a spawning season pumping hiatus, and Alden Laboratories' extensive literature library on intake screening technologies and their effectiveness was used in assessing the value of wedgewire screens for protecting fish from intake impacts. The RRWSG provided results of salinity and safe yield modeling to the Panel and the Panel used the results to assess potential effects of any changes in flows and salinity on Mattaponi River fish species.

The major supporting information used by the Panel in their deliberations is provided along with this report as Appendices. The Panel collectively developed the material included in Appendices C and D, dealing with the development of pumping hiatus triggers, and the design of preoperational and entrainment monitoring programs. Panel members had an opportunity to review and comment on drafts of Appendix E, which were prepared by Alden Laboratories. The Panel did not review or verify the accuracy of all of the material presented in Appendices F and G, which were provided by the City of Newport News and Malcolm Pirnie, and Appendix H, which was provided by Marine Acoustics. The Panel accepted the material presented in those appendices and used the information in their deliberations and to formulate their recommendations.

What types of impacts did the Panel identify that could be imposed on Mattaponi River fish species by the KWR intake?

The Panel identified four modes of potential impact from the KWR intake installation and operation that warranted assessment: construction (both short-term effects during construction, and long-term effects as a result of the existence of the intake structures in the river); water withdrawal effects (entrainment, impingement and screen contact); changes in flow and salinity; and, noise effects.

What were the Panel's conclusions regarding potential for short-term construction impacts?

In-river construction is prohibited between February 15 and June 30 by the KWR VDEQ Water Protection Permit. Thus, the majority of the more sensitive early life stages of any spring spawning species (i.e., all anadromous species and most resident species) will not be exposed to any construction effects during the spring spawning period. Fish and other aquatic organisms occurring in the vicinity of the proposed intake location outside of this time period could be potentially exposed to effects of construction activities. However, dredging for placement of the intake screen supports (the principal potential construction stressor) will be conducted within a sheet pile enclosure, and loading of dredged sediments into transport barges will be done within a temporary turbidity curtain. The procedures will result in minimal dispersion of suspended sediments and turbidity. No significant impacts would be expected from such minimal environmental perturbation.

What were the Panel's conclusions regarding potential for long-term construction impacts?

Placement of the KWR intake structure in the Mattaponi River is analogous to the addition of any hard structure (e.g., pier, bridge, artificial reef) to a portion of a waterbody in which none had previously existed. While both forage fish and predators may concentrate in the vicinity of such a structure, those concentrations would result from redistribution of existing populations. Fish aggregations around the intake may make fish more vulnerable to exploitation by fishermen. The intake would not hydraulically create concentrations of non-motile life stages (e.g., eggs and larvae) except during infrequent slack tide periods. The creation of increased densities of predators and prey may result in some increase in predation rates, because of their enhanced proximity, but it is the opinion of the Panel that any such increase would likely be small and most likely inconsequential within the context of the Mattaponi River ecosystem.

How did the Panel address the entrainment/impingement impact issue?

The existing KWR record illustrated that there was considerable uncertainty with regard to the magnitude of impacts to the American shad population that would result from KWR water withdrawal and also about the significance of those impacts to that population. In lieu of attempting to scientifically resolve these complex issues and in the interest of moving their project forward, the RRWSG instructed the Panel to develop a means of establishing a pumping hiatus that would, with a high degree of reliability, encompass the period during which vulnerable early life stages of American shad would be present in the vicinity of the KWR intake. Such a hiatus was anticipated to also provide a high level of protection to early life stages of the other potentially vulnerable species.

How did the Panel develop the protocol for an effective pumping hiatus?

Insufficient American shad early life stage and temperature data were available from the Mattaponi River or other Chesapeake Bay tributaries from which to evaluate potential triggers that could be used to define a hiatus appropriate for protecting American shad. Appropriate data were available from a 30-year sampling program in the Hudson River that could be used as surrogate data for investigating potential temperature triggers and defining an appropriate hiatus period. Eggs and yolk-sac larvae were identified as the vulnerable American shad early life stages that required protection. Temperature was identified as the best trigger for a hiatus because it is easily measurable and a reliable indicator of presence of vulnerable life stages. Exploratory analyses, based on Hudson River data, showed that ceasing pumping when water temperatures reached 10 ^{o}C and restarting pumping when water temperatures reached 22 ^{o}C would provide absolute protection to 100 per cent of yolk-sac larvae and absolute protection to no less than 97 percent of shad eggs in 18 of 18 years for which complete data were available. The duration of a pumping hiatus defined by those temperature triggers would vary annually from 44 to 83 days, averaging 61 days. The RRWSG determined from safe yield modeling that the KWR would still be capable over the long term of meeting its water supply objectives with hiatuses of that average magnitude during non-drought emergency years. Their explanation for that capability is that water stored in the KWR and other elements of the water supply network would satisfy demand over extended periods of time when no or limited withdrawal from the Mattaponi River would be permitted because of the implemented hiatus or VDEQ permit minimum instream flow constraints.

How can results from Hudson River data be applied to the Mattaponi River American shad population?

The Panel recognized that while analyses of the surrogate Hudson River data established the feasibility of using temperature as a trigger for an effective pumping hiatus, triggers developed from the Hudson data might not be reliable for such use in the Mattaponi. This might occur if temperature trends or American shad spawning behavior differed between the two rivers. Thus, the Panel recommended to the RRWSG the inclusion in the project of an intensive long-term preoperational ichthyoplankton monitoring program. This program would provide 8 or more years of detailed data on water temperature and early life stage density and distribution over time. Those data would then be used, following the same methods used on the Hudson River surrogate data, to establish Mattaponi River-specific temperature triggers that would define the pumping hiatus period.

While the RRWSG desired to provide as close to 100 percent absolute protection to American shad as possible, the Panel recognizes the many uncertainties associated with collection of biological and environmental data in the field and the natural and sampling variability that are likely to be encountered in long term studies of this type. High variability in ichthyoplankton density estimates is to be expected, particularly at the beginning and end of the spawning period when densities of organisms are very low. These factors make accurate assurance of 100 percent absolute protection impossible. Because the magnitude of variability and uncertainty will not be known until a number of years of data are available from the preoperational monitoring program, a priori statistical confidence limits on magnitude of protection cannot be established. Taking these factors into account, the Panel decided that feasible criteria for levels of protection, based on results of analyses of Hudson River data, would be a minimum of 97 percent absolute protection of the standing stocks of eggs and yolk-sac larvae in 7 of 8 years of study, and no less than 95 percent absolute protection of the standing stocks of eggs and yolk-sac larvae in any single year. This latter lower protection percentage is in recognition of potential for unusual, infrequent events impacting study results. To further reduce potential for uncertainty, the Panel has recommended that RRWSG commit to implementation of a pumping hiatus over a temperature range of at least 12 ^{o}C, corresponding to the range between the temperatures of 10 ^{o}C and 22 ^{o}C, even if results from the preoperational monitoring program suggest a smaller temperature range would achieve the protection objectives. Because of the RRWSG commitment, results of preoperational monitoring could potentially result only in an expansion of the hiatus temperature range beyond a 12 ^{o}C range. In addition, the Panel is also recommending concurrent implementation of a hatch date study, that will document the “date of birth” of juvenile American shad produced in each year. These data would contribute to verifying the efficacy of the Mattaponi River-specific hiatus temperature triggers derived from the preoperational icthyoplankton monitoring surveys.

Will the pumping hiatus provide absolute protection to all species vulnerable to intake impacts?

Any vulnerable life stages that may be present in the vicinity of the intake outside of the pumping hiatus time period would have potential for experiencing intake effects. Analysis of the surrogate Hudson River data suggest that the 10 ^{o}C to 22 ^{o}C hiatus would encompass the period when nearly all American shad eggs and yolk-sac larvae would be present, and when high percentages of early life stages of other vulnerable species would be present in most years. The Panel’s review of the most current studies of wedgewire screen effectiveness and hydraulic characteristics of wedgewire intake screens indicated that the intake design provides a high level of protection from impingement, entrainment and screen contact to any relatively immotile organisms that might be present within the area of influence of the intake outside the pumping hiatus. Thus, the project as currently designed provides multiple layers of protection that cumulatively provide to fish a high level of protection from water withdrawal impact.

Are there other circumstances under which vulnerable life stages may be exposed to water withdrawal effects?

The KWR Project, as proposed, includes suspension of the spring pumping hiatus in years when a drought emergency declared by the State of Virginia is in effect in the spring. Safe yield modeling results provided by the RRWSG to the panel indicate that the frequency of occurrence of drought emergency years in which spring withdrawals may be allowed, based on data from 1928 to 2001, is 2 in 74 years. That frequency is projected for conditions under which the KWR supply capacity is fully utilized, in the year 2040. The RRWSG indicates that model runs using the current demand, which is about two thirds of the 2040 demand, produce no spring drought emergencies in the 74 years projected. Thus, probability of a spring drought emergency being declared is likely to be less than 2 in 74 for several decades. In drought emergency years when spring water withdrawal would be allowed, it could only be done in compliance with VDEQ permit minimum instream flow (MIF) requirements. Additional modeling illustrates that, under projected drought emergency conditions, MIFs restrict withdrawals in five of six spring months modeled. The MIF restrictions resulted in monthly withdrawals ranging from 14 percent to 66 percent of the permitted maximum withdrawal rate in those five months. In the one month where maximum withdrawal was projected to occur (March 1955), river flow was 630 mgd and the maximum withdrawal represented only about 12 percent of freshwater flow. Thus, spring withdrawals during drought emergencies are likely to be both infrequent and of limited magnitude. MIFs will also significantly constrain, and in some years preclude, withdrawals in summer and fall of low flow years. The KWR intake design provides a high level of protection from impingement, entrainment and screen contact to any relatively immotile organisms that might be present within the area of influence of the intake when any water withdrawal is occurring, further reducing the potential for impacts in years of spring withdrawals. The RRWSG anticipates that entrainment monitoring will be required as part of the VDEQ permit-mandated biomonitoring program for the KWR. Such entrainment monitoring, to be implemented when water withdrawal is occurring and early life stages are present within the area of influence of the intake, will provide a means of verifying the protection levels afforded by the design and mode of operation of the KWR intake.

Are any other life stages of Mattaponi River fish species vulnerable to water intake effects?

The KWR intake screens have very small (1 mm) slot widths and very low through-slot water velocities (< 0.25 ft/sec). Only totally or nearly immotile life stages (i.e., eggs and early larval stages) would be unable to avoid the intake screens. Thus, juvenile and adult stages of nearly all Mattaponi River species have swimming capabilities sufficient to avoid any contact with or effect from the intake screen.

Why did the Panel not conduct any modeling or analyses to project the potential consequences to adult populations from any losses of early life stages that are anticipated to occur?

Debate concerning population-level significance of losses of early life stages is not unique to the KWR, and has been extensive over decades of regulatory proceedings regarding the consequences of power plant water withdrawal-induced mortalities to early life stages of fish. Such debate arises as a result of many scientific uncertainties, including such factors as biological differences among fish populations in different geographical regions and compensation, the possibility that anthropogenic loss of early life stages may be offset by density dependent increases in survival of the remaining individuals. Any attempt to quantitatively and reliably project effects of early life stage losses to adult population levels would require data and information not currently available for the Mattaponi River American shad population. Thus, as requested by the RRWSG, the Panel sought to develop a pumping hiatus that would provide nearly complete protection to vulnerable early life stages, and thus avoid early life stage losses and obviate the need to assess their population-level significance.

Did the Panel consider how KWR water withdrawals might change Mattaponi River salinity regimes and how such changes might affect fish populations?

The Panel did not undertake independent analyses or modeling to address the salinity issue, but relied on prior modeling conducted by VIMS and safe yield modeling conducted by Malcolm Pirnie for the RRWSG for our evaluation. The potential consequences to salinity regimes from water withdrawals would be migration of the fresh water/salt water interface upstream from where it would naturally occur in the absence of withdrawals, and a change in a portion of the tidal freshwater portion of the river into an oligohaline environment. It is important to recognize that natural annual variability in river flows result in significant changes in the salinity regime from year to year. Implementation of a pumping hiatus in most years precludes any KWR-induced changes in salinity regimes during the spring spawning period in those years. Given the special concern regarding potential project impacts to anadromous fish species, particularly American shad, at issue is whether water withdrawals would alter salinity regimes in summer and fall, when the tidal freshwater portions of the Mattaponi serve as nursery grounds for those species. Our interpretation of the modeling results presented to the Panel indicated that the minimum instream flows (MIFs) imposed on the KWR in the VDEQ Water Protection Permit often preclude and consistently restrict the magnitude of water withdrawal during most summer and fall periods, when river flows are low. These are the periods when salinity regimes are most likely to be affected by withdrawal of the limited freshwater available. The modeling results also indicated that changes would be so small as to be immeasurable, given natural variability and measurement error. An additional level of protection against significant impacts to fish from changes in salinity regimes is provided by conditions D.3 and D.4 in the KWR Water Protection Permit. These permit conditions require the RRWSG to monitor salinity regimes so as to detect any salinity-induced changes in the spawning and nursery grounds used by anadromous fish. Given that no significant changes in salinity regimes are predicted, and that a comprehensive monitoring program will provide a basis for confirming those predictions, no long-term consequences to fish are anticipated.

Did the Panel consider whether expected magnitude of withdrawals and potential consequences to Mattaponi River salinity regimes would be different when the reservoir is initially being filled?

In response to a question raised by VIMS staff at the meeting with the Panel on March 19, the Panel requested information from the RRWSG on whether the safe yield model predictions of withdrawal magnitudes provided to the Panel encompassed the period of reservoir filling. The RRWSG informed the Panel that the duration of the filling period will be primarily a function of climate variability. VDEQ permit MIFs would be in force during the period of filling. While the calculated minimum fill time would be approximately 175 days if water were withdrawn continuously at the maximum design capacity rate of 75-mgd, the safe yield modeling, which accounts for the effects of the MIFs, indicate that fill time will be on the order of 1,000 days under average to slightly dry conditions. The RRWSG indicated that the modeled seasonal average withdrawal data provided to the Panel would be very close to withdrawals that would expected to occur during the reservoir filling period. For that reason, the Panel's conclusion regarding lack of impact to salinity regimes is applicable to operations under both normal conditions and the period of reservoir filling..

Did the Panel consider the potential for ecosystem effects to occur as a result of the KWR water withdrawals?

VIMS staff raised the issue of potential for ecosystem effects at the March 19 meeting with the Panel. The Panel has considered this issue from the perspective of how any such effects could be generated by the KWR project. The VDEQ permit MIFs constrain KWR water withdrawals in such a manner as to preclude significant effects to natural salinity regimes in the river, as was already noted. The MIFs also exert greatest constraint on withdrawals during periods of low flow, such as summer and fall. Largest withdrawal rates occur during periods of highest river flow. Thus, most of the water withdrawn from the Mattaponi River comes from "skimming" water off the highest inflows (e.g., pumping at maximum withdrawal rate would be likely to occur during a period of high precipitation and runoff, if the reservoir were not at capacity and if the withdrawal did not violate the MIF). The maximum predicted average seasonal withdrawal rate is 6.3 percent of the Mattaponi River freshwater inflow. Variations in withdrawal rates around the average will obviously occur. The maximum upper quartile value for seasonal withdrawal rate as a percentage of freshwater inflow is 10.9 percent, meaning that the percentage of freshwater withdrawn will be less than 10.9 percent for 75 percent of the time. Given that such withdrawals were not predicted to significantly alter salinity regimes in the river, and that the low percentage of river inflow removed via withdrawals would not significantly affect phytoplankton and zooplankton, which have high population turnover rates, the Panel concluded that ecosystem-level effects were highly unlikely.

How did the Panel address the potential for intake noise to affect fish populations?

The issue of potential impacts to fish populations from noise generated by the KWR water intake was raised by VIMS and by a number of individuals testifying at the VMRC KWR hearing. The implementation of a pumping hiatus during the primary spawning period for all of the Mattaponi River anadromous fish species ensures that anadromous fish will not encounter any KWR intake-related noise during a major part of their spring spawning migrations in years of normal operation. But since no data was available on the magnitude and frequencies of sounds that might be generated by such an intake, the Panel recommended to the RRWSG that a survey be conducted of sounds produced at a similar wedgewire screen intake, located in Lake Gaston, that operates in a manner similar to that proposed for the KWR intake. Based on the sound measurements at the Lake Gaston water intake, we anticipate no effects to fish from additional sounds produced by normal operation of the KWR intake. The results of the field studies indicate that there are no sounds generated by the intake at the high frequencies to which the American shad, blueback herring and alewife are especially sensitive. There may be momentary startle responses from a rapid increase in low-frequency noise due to the cleaning air bursts, which would occur infrequently. Frequency of cleaning air bursts may be as low as once per week to as much as 2 to 3 times per day, depending on site specific characteristics that may vary in response to environmental conditions and season (e.g., amount of suspended debris, such as leaves). Total duration of air burst cleaning of the screen array would be about 90 seconds for any single cleaning event. These brief and infrequent cleaning events would not result in a sustained adverse effect on normal fish behavior.

Did the Panel consider other mitigation measures that should be included in the KWR project?

The procedures to be followed during construction and the imposition of a pumping hiatus during the spring spawning period can be considered impact avoidance measures that have been incorporated into the KWR project. Two mitigation measures previously proposed by the RRWSG were reviewed by the Panel. The RRWSG's offer to provide 1 million shad larvae for release into the Mattaponi River as mitigation for any losses caused by water withdrawals was considered unnecessary with implementation of a pumping hiatus. In addition, issues of genetic bottle-necking that might result from hatchery augmentation programs suggested against implementing that mitigation measure. The RRWSG's offer of funding to VDGIF for construction of fish passage facilities was reviewed and evaluated for the magnitude of potential enhancement of anadromous fish populations that might result. The fish passage measures included in the KWR VDEQ permit could potentially result in the addition of thousands of individuals to the annual production of local populations of river herring, shad, and other anadromous fish species if the newly accessible habitat were fully utilized by those species.

Based on their assessments and deliberation, does the Panel support or oppose the KWR project?

The Panel was not asked to take a position on the KWR project as a whole. We were instructed to review the proposed KWR intake, consider the issues raised, conduct analyses and reviews to help us understand and address those issues, and make recommendations on how to ensure that the KWR intake will have virtually no effect on the Mattaponi River American shad population and minimal effect on all other species that occur in the river. We recommended, and the RRWSG has incorporated into the KWR project, procedures for development and implementation of a pumping hiatus defined by temperature triggers that would be implemented in years of normal operation. We believe that a pumping hiatus implemented following our recommended procedures will assure nearly complete protection to the vulnerable life stages of the Mattaponi River American shad population in years of normal operation. We incorporated hatch date analysis of juvenile American shad in our recommendation to contribute to verification of the efficacy of the pumping hiatus. The hiatus is expected to provide a high level of protection to vulnerable life stages of many other species.

The hiatus would not be implemented in years in which a drought emergency is in effect in the spring, which is projected to occur with low frequency. We have concluded, based on the information provided to the Panel by Alden Laboratories, that organisms present within the area of influence of the intake when the hiatus is not in effect (during drought emergency years and outside the hiatus trigger temperatures) are afforded a high degree of protection by the design of the KWR intake (wedgewire screens in a linear array parallel to the river channel, fine mesh, low through-slot velocities and high sweep velocities) and VDEQ permit minimum instream flows. The magnitude of that protection to the vulnerable life stages of all species is difficult to quantify, but because the benefits of each of the factors are cumulative, the total level of protection is expected to be high. In addition, the RRWSG anticipates that entrainment monitoring will be required as part of the VDEQ permit-mandated biomonitoring program. The entrainment monitoring will allow verification of the protection levels anticipated.

The hydrodynamic modeling results provided to the Panel indicate that salinity changes due to KWR water withdrawal will be very small and most likely immeasurable and thus insufficient to affect fish populations. No significant short-term or long-term construction impacts are likely. Thus, we believe the project as currently proposed, including our monitoring and pumping hiatus trigger development recommendations, will not significantly impact the Mattaponi River American shad population or the other fish species found in the river. Because our assessment is to a great extent based on projections of future events from past data, it must a priori have some degree of associated uncertainty. However, the requirements for biomonitoring and salinity monitoring specified for the KWR project in the VDEQ Water Protection Permit provide the means of continuously assessing whether all the projections used in our assessment prove in fact to be valid. The VDEQ permit must be renewed every five years, thus providing the means of modifying facility operations further should any significant deviations from projections become evident.

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FOREWORD

In order to fully address issues raised concerning the potential for the proposed King William Reservoir water withdrawals to adversely impact Mattaponi River fish populations, the Regional Raw Water Supply Study Group (RRWSG) convened the King William Reservoir Fisheries Panel. The charge to the Panel was to evaluate the potential for the project to impact Mattaponi River fish resources and to provide recommendations on monitoring, operation and mitigation that would minimize or eliminate impacts to fish species. The RRWSG requested that, to the extent possible and feasible, the Panel develop measures that would result in no impact of KWR water withdrawal on the Mattaponi River American shad population and minimal impacts to other important Mattaponi anadromous and resident fish populations. The Panel is composed of fisheries scientists with demonstrated expertise in all aspects of fish impact assessment and project design and operations that might affect Mattaponi River fish populations. Members of the panel include:

- Mr. Stephen Amaral, Director, Fisheries, Alden Research Laboratory, Inc., Holden, Massachusetts; special expertise in wedgewire screen technology and effectiveness of various water intake screening technologies for fish protection
- Dr. Charles Coutant, Distinguished Research Ecologist, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee; special expertise in water withdrawal effects on anadromous fish populations and monitoring and mitigating those effects
- Mr. William Dey, Senior Scientist, ASA Analysis & Communication, Inc., New Hampton, NY; special expertise in fish damage and impact assessments in estuarine habitats
- Dr. Gregory Garman, Professor, Virginia Commonwealth University, Richmond, Virginia; special expertise in monitoring and assessment of Virginia riverine anadromous and resident fish communities
- Dr. Karin Limburg, Associate Professor, SUNY College of Environmental Science & Forestry, Syracuse, New York; special expertise in American shad and river herring life history and biology
- Dr. William A. Richkus, Vice President of Versar, Inc., Columbia, Maryland (Fisheries Panel Coordinator); special expertise in estuarine and anadromous fish monitoring, fish impact assessment and fisheries management
- Dr. Kenneth Rose, Professor, Department of Oceanography & Coastal Sciences/Coastal Fisheries Institute, Louisiana State University, Baton Rouge, Louisiana; special expertise in fish population and impact assessment modeling.

Versar, Inc., an environmental and engineering services firm headquartered in Springfield, Virginia, was contracted to coordinate KWR Panel activities and was responsible for preparation of this report. Versar's Dr. William Richkus served as primary author for preparing report text, integrating text and material from other documents and incorporating report sections prepared by other Panel members. Mr. William Dey, in addition to his participation as a Panel member, provided analytical support to the Panel, conducting analyses and preparing data presentations requested by the Panel. Mr. Dey also prepared Appendix C of the report, describing the approach for development of temperature triggers for a pumping hiatus as a means of ensuring protection of American shad early life stages. Mr. Stephen Amaral prepared Appendix E of the report section, dealing with wedgewire screen effectiveness for protection of vulnerable life stages of American shad and other Mattaponi River fish species. Other members of the staff of Alden Laboratories contributed to preparation of Appendix E; the qualifications of Alden Laboratories are also presented in this appendix. Dr. Gregory Garman prepared initial drafts of the section of the report that addresses the potential vulnerability of Mattaponi River fish species to water withdrawal entrainment impacts. Dr. Charles Coutant prepared the portions of the report addressing potential impacts of KWR intake noise on fish. Malcolm Pirnie and the City of Newport News prepared Appendices F and G, which present information on safe yield modeling of the proposed KWR project and details on the design and operation of the project as is presently proposed. Marine Acoustics, Inc. conducted the intake sound studies and prepared the reports presented in Appendix H; their qualifications are also included in this appendix. Drs. Kenneth Rose and Karin Limburg participated in Panel discussions and interactions and served as reviewers of draft versions of the report. The Panel met with representatives of the City of Newport News Waterworks Department, representing RRWSG, at the initiation of their effort, during preparation of, and after completing their draft report. In addition, representatives of the RRWSG participated in Panel conference calls during the course of the Panel's evaluations. Through the course of these interactions, RRWSG representatives raised questions and offered suggestions regarding draft material provided by the Panel. However, in no instance was the Panel directed by RRWSG representatives to alter or modify any finding or conclusion arrived at over the course the Panel's deliberations. A working draft of this report was provided to the Virginia Marine Resources Commission (VMRC) staff and its technical consultant, Virginia Institute of Marine Science (VIMS) on March 5 and the Panel met with VMRC and VIMS staff on March 19 to discuss findings presented in the draft report and identify issues that both staffs recommended be addressed in the final report.

Of the Panel members, Mr. William Dey, Dr. Gregory Garman, and Dr. William Richkus have previously provided contractual support to the Regional Raw Water Supply Study Group (RRWSG) in addressing various aspects of KWR fish impact issues. None of the other Panel members have had any prior involvement with the KWR project, either on behalf of the City or of any other project stakeholders. None of the Panel members have any vested interest in the proposed reservoir project. All panel members were compensated for their time and reimbursed for travel and other incurred expenses. Resumes of the Panel members are presented in Appendix A of this report.

1.0 INTRODUCTION

The Regional Raw Water Supply Study Group (RRWSG) was created in 1987 to examine the long-term water supply needs of the Lower Peninsula area of southeast Virginia and to develop a plan for meeting those needs (USACOE 1997). To meet anticipated demand increases and after evaluation of options available for meeting those increasing demands, the RRWSG proposed to construct a new 1,526-acre King William Reservoir (KWR) by impounding Cohoke Creek in King William County. Water for the filling of the KWR and for maintenance of its water supply would come from the Cohoke Creek watershed, supplemented by water withdrawn from the Mattaponi River (USACOE 1997). A wide range of issues has been raised concerning the potential adverse impacts of construction and operation of the KWR, from cultural and socioeconomic effects to consequences to natural resources. Included among these many diverse issues is a subgroup of issues relating specifically to the potential impacts of withdrawal of water from the Mattaponi River on anadromous and resident fish populations of that river. The issues in this subgroup pertain to impacts that might be caused by construction of the intake, the design of the intake structure, its modes of operation, and the results of water removal on fish populations and habitat in the river. Commenters have expressed particular concerns regarding the potential for the project to impact the Mattaponi River American shad (*Alosa sapadissima*), a population which has historically been one of the most productive in Virginia waters and which is currently recovering from depressed levels (Mann 2003).

The King William Reservoir Fisheries Panel was formed by the RRWSG to address all Mattaponi River fish impact issues that have been raised about the KWR water intake. Panel members are listed in the Foreword, and their resumes are presented in Appendix A. The Panel's charge was to evaluate the potential for the KWR project to impact the Mattaponi fish populations and to provide recommendations on monitoring, operation and mitigation that would ensure that there would be virtually no impact of KWR water withdrawal on the Mattaponi River American shad population and minimal impacts to other important Mattaponi anadromous and resident fish species. The Panel's evaluations were based solely on an intake in the location that has been proposed by the City. That proposed intake is described in Section 2, below.

This report presents the results of the Panel's discussions and deliberations and is the consensus of panel members on each of the matters addressed. The Panel was appraised of the various fish-related issues raised in the VMRC hearing and also was provided with information on prior assessments of impacts to fish to provide context for their activities and also to identify major issues on which stakeholders had presented differing views. A summary of prior findings considered by the Panel is presented in Appendix B. To the maximum extent possible, the Panel relied on scientific peer-reviewed results and findings as the basis for their deliberations and conclusions. This report also presents the results of unpublished data and analyses that were conducted at and under the direction of the Panel, subject to review by the Panel and revised or modified based on that review. In several instances, published findings and/or relevant data on a particular topic were not available, and detailed analyses to address an issue were not feasible. In these instances, which are identified explicitly in the text, a consensus expert opinion of the

Panel was developed that was based on the combined experience and expertise of the Panel members.

The major supporting information used by the Panel in their deliberations is provided along with this report as Appendices. The Panel collectively developed the material included in Appendices C and D, dealing with the development of pumping hiatus triggers, and the design of preoperational and entrainment monitoring programs. Panel members had an opportunity to review and comment on drafts of Appendix E, which were prepared by Alden Laboratories. The Panel did not review or verify the accuracy of all of the material presented in Appendices F and G, which were provided by the City of Newport News and Malcolm Pirnie, and Appendix H, which was provided by Marine Acoustics. The Panel accepted the material presented in those appendices and used the information in their deliberations and to formulate their recommendations.

The organization of this report is as follows. The proposed design, construction and operation of the KWR Mattaponi River intake are described in Section 2. This information was provided by the RRWSG, and drawn from Appendix G, which was prepared by the City's engineering support contractor, Malcolm Pirnie and the City of Newport News. These descriptions provided the basis for the Panel's evaluation of potential impacts to fish and the Panel's development of modes of operation and mitigation measures necessary to achieve the objectives of minimal impact to American shad and other vulnerable important Mattaponi River fish species. In Section 3, the physical and biological characteristics of the Mattaponi River within the area of influence of the KWR intake are briefly described. These characteristics were taken into account by the Panel in their assessments and deliberations. Section 4 describes the resident and diadromous fish species that are found in the Mattaponi River and evaluates the level of vulnerability of each species to effects of the water intake, based on their biology and life history characteristics and the design and proposed mode of operation of the water intake. In Section 5, the potential impacts of the KWR on potentially major Mattaponi River fish species are assessed, taking into account the mitigation measures incorporated into the project to eliminate or minimize impacts. The discussion of potential impacts is broken down according to potential impact source: construction; impingement on intake screens; entrainment through intake screens; salinity changes; and noise. Detailed analyses and literature reviews that were performed to support the Panel's deliberations are presented in appendices and referenced in the text. Section 6 discusses mitigation measures that have been offered by the RRWSG for this project. Section 7 presents the Panel's findings and conclusions, and Section 8 lists report references.

2.0 PROPOSED KWR MATTAPONI RIVER INTAKE DESIGN, CONSTRUCTION, AND OPERATION

2.1 INTAKE DESIGN

As noted in the Introduction, water from the Mattaponi River will contribute to filling of the KWR and for maintenance of the water supply in the reservoir once it becomes operational. The proposed location for the KWR intake is at Scotland Landing, approximately 24 miles upstream of the mouth at West Point. Water will be withdrawn through an intake structure located approximately 110 feet (at MLW) from the south shore of the Mattaponi River (Figure 2-1; note that all figures in this section are drawn from the Appendix G). This location places the intake along the outside edge of a bend in the river. Along the opposite shore is the Garnetts Creek Marsh.

A total of twelve wedgewire screens, each a maximum of 7 feet in diameter by approximately 7 feet long will be installed. The screens will be constructed to form six tee screen assemblies (Figure 2-2). Three of these tee screen assemblies will be connected to each of the two intake lines. All six tees will be aligned in a single row parallel to the shoreline (see Figure 2-1) so organisms and any debris in the water column will be swept along and then off the surface of the screens and not be forced into the screen face. The screens will be removable (by means of bolted connections) from the intake lines for major maintenance or replacement and flanged plates will be available to plug the resulting open riser pipe. The KWR intake was designed to meet or exceed the water intake screening guidelines established by the Commonwealth (Virginia Department of Game and Inland Fisheries, VDGIF) to minimize fish mortality associated with impingement and entrainment (Gowan et al, 1999).

The screens will be located in a naturally deep portion of the Mattaponi River. The existing water depth at the screen location varies from approximately 21 to 23 feet[MSOffice1] at Mean Low Water (see Figure 2-1). The top of the screens will be set 8 feet below Mean Low Water. This will provide at least 6 feet of vertical clearance between the bottom of the screens and the restored river bottom. Each wedgewire screen will have a slot-width of 1 millimeter (Figure 2-3). This intake configuration would result in maximum through-slot velocities of 0.25 fps if the intake were withdrawing water at its maximum capacity of 75 mgd.

A manually controlled air backwash screen cleaning system will be installed with the screens to allow the screens to be cleaned. This system cleans debris from the screen surface by releasing a burst of compressed air from a small diffuser pipe located within the screen. The water turbulence created by the air bubbles and the rising air bubbles themselves lift debris off the screen, allowing it to be carried away by the natural river current. The screens will likely be cleaned sequentially, starting from one end of the screen array and proceeding to the other in the direction of the tidal flow in the river that exists at the time of cleaning. With this approach, debris lifted off the first screen to be cleaned, which might settle on the next screen, will be removed from the second screen as soon as it is cleaned. After all the screens have been air

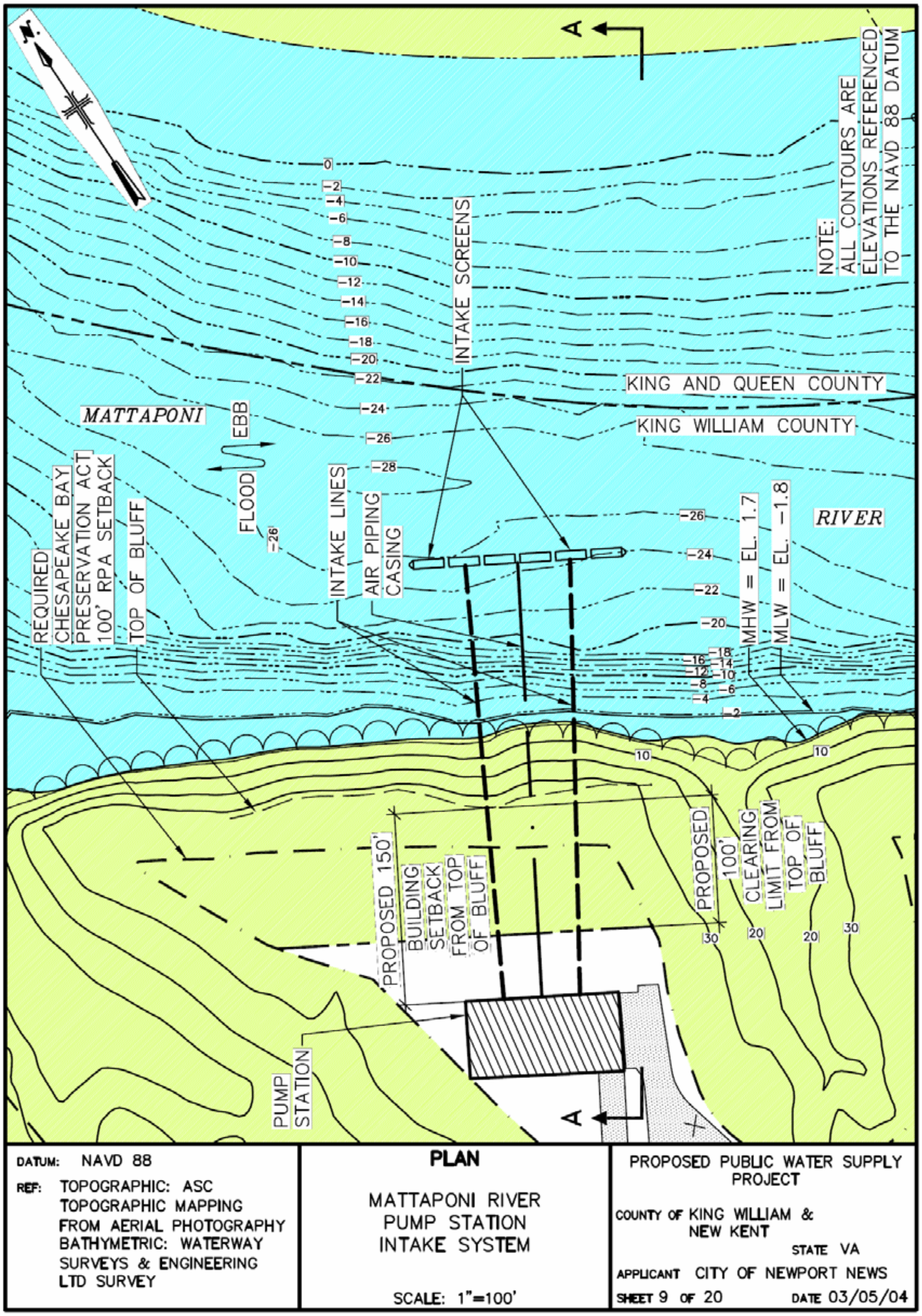

Figure 2-1. Intake screen location

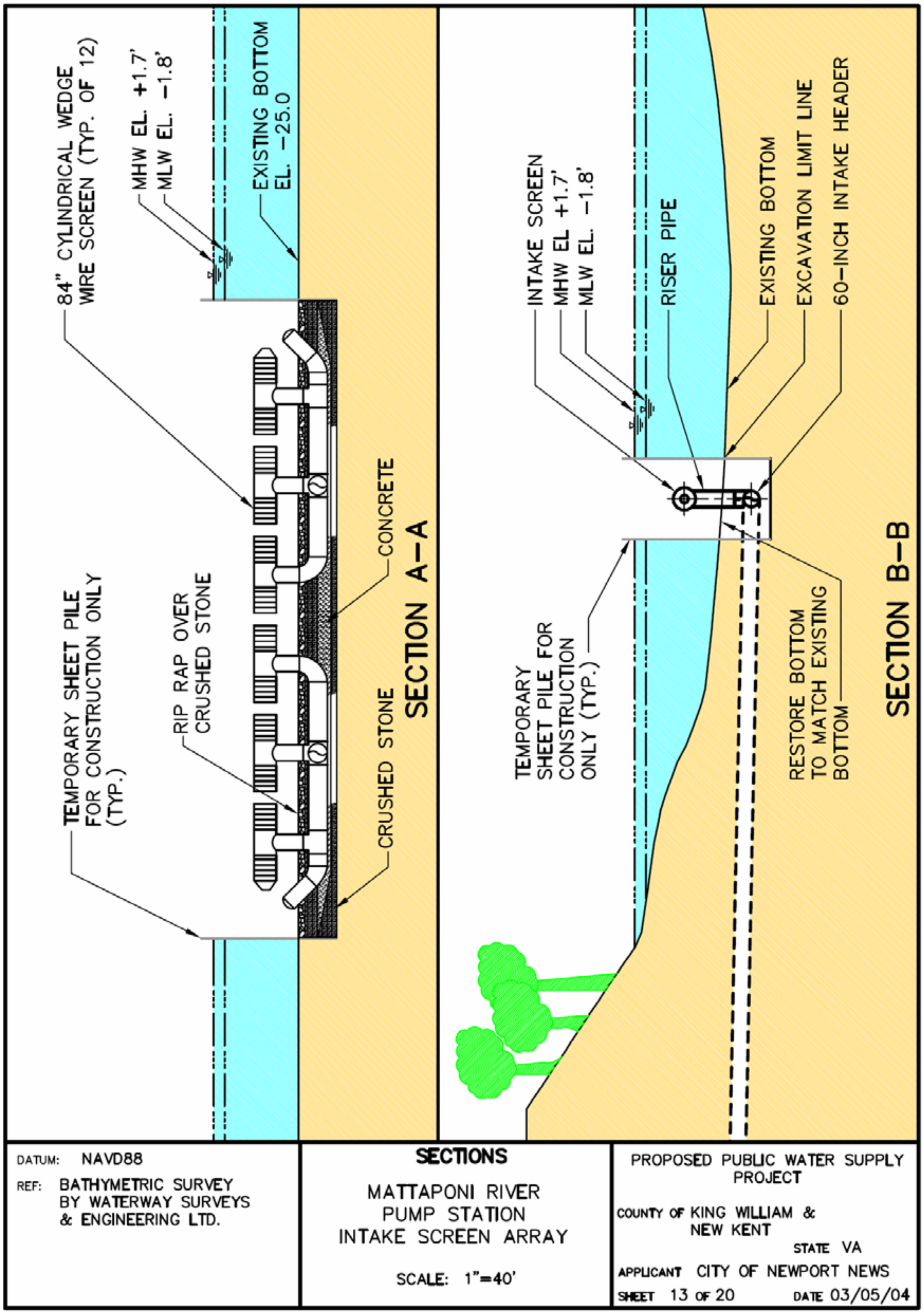

Figure 2-2. Tee screen arrays

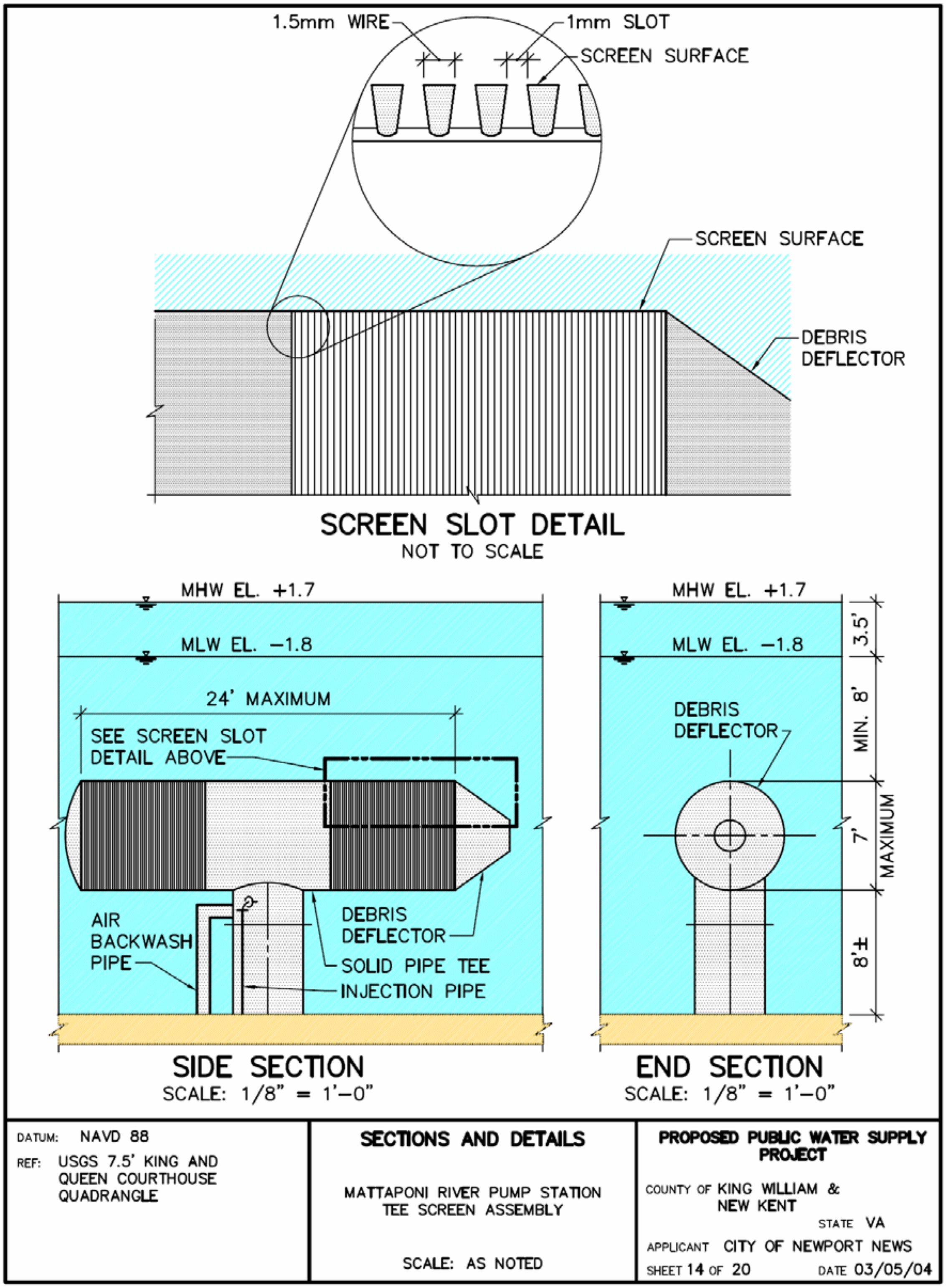

Figure 2-3. Screen mesh and design detail

backwashed, the debris that had settled on the screens will have been returned to the flowing water of the river.

Cleaning is expected to be required on an intermittent basis only, although the exact requirements cannot be precisely predicted because they are a function of site-specific characteristics. Similar installations have reported backwash frequencies varying from once per week to three times a day. The air burst backwash of each tee screen assembly will include approximately 15 seconds of high intensity air release and have a total duration of approximately 90 seconds.

2.2 INTAKE CONSTRUCTION

The VDEQ Water Protection Permit for the KWR (Permit No. VWPP#93-0902) prohibits intake construction activity between February 15 and June 30. Estimated time for the in-river portion of intake construction is 6 months. Dredging and work from barges will be required to construct the buried intake screen header piping, concrete encasement, and riser pipes. Clamshell or backhoe excavator equipment will be used for dredging within a sheet pile enclosure, to minimize the area of disturbance on the bottom and the movement of turbid water created during the excavation phase of the work. Barges will be loaded with the dredged sediments within an area enclosed by a temporary turbidity curtain. (Figure 2-4). The total estimated volume of material to be excavated and disposed of at Craney Island, an existing permitted dredged material disposal site, is 2,500 cubic yards.

During construction, an unobstructed 100 foot wide corridor with a depth of at least 10 feet at MLW will be maintained between the work area and the north shore of the river (Figure 2-4), so that the movement of recreational and commercial boating traffic on the river as well as mobile aquatic biota will not be impeded. The intake facilities will be located in King William County at least 50 feet away from the King and Queen County line. The two parallel 60-inch (internal diameter) intake and other ancillary lines will be installed using microtunneling technology or other trenchless methods. The existing shoreline, any shoreline wetlands that may exist, and the wooded bluff will not be disturbed by the installation of these pipes.

The river bottom will be restored after construction to match the pre-existing bottom contours (see Figure 2-2). The surface will be restored with riprap, in order to minimize the potential for damaging scour to occur around the base of the riser pipes. Only granular and stone materials will be used for backfill of the intake pipes and associated concrete embedment. Dredged sediments will not be reused in any way at the site. The intake piping will extend a total of approximately 140 feet under the river bottom from the mean high water line.

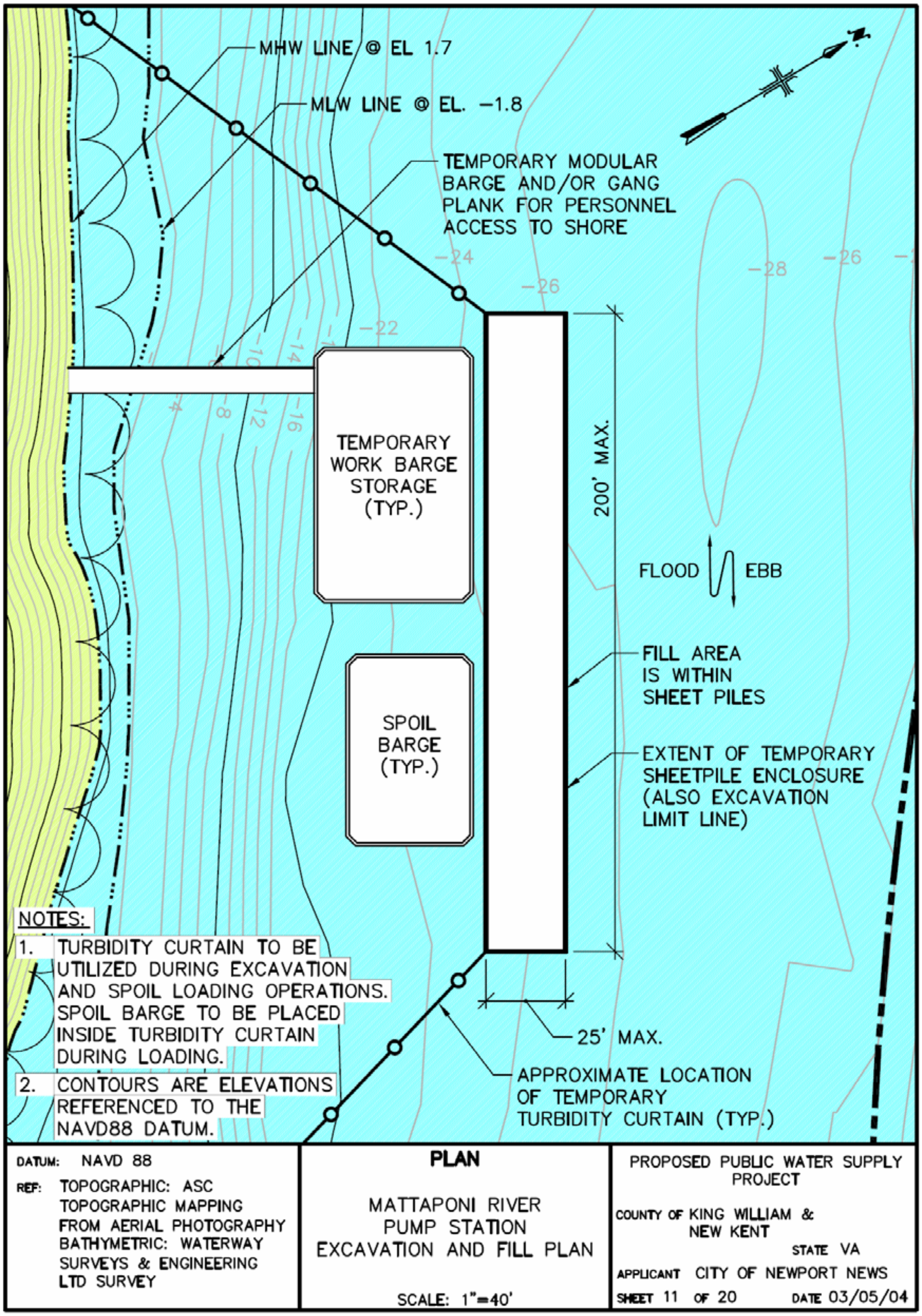

Figure 2-4. Construction mitigation designs

2.3 INTAKE OPERATION

2.3.1 Years of Normal Operation

The KWR Mattaponi River intake will be operated in compliance with a Virginia Water Protection Permit issued for the project by the Virginia Department of Environmental Quality (VDEQ). This permit specifies minimum instream flow (MIF) requirements for the Mattaponi River at Scotland Landing that constrain the amount of water that can be removed from the river during most times. These MIF values are termed the "80 percent exceedance" MIFs. KWR water withdrawals that would result in freshwater flow to the river downstream of the intake to drop below these MIF levels are not allowed (Table 2-1).

As second set of MIFs, termed the "40/20 Tennant" MIFs are implemented at any time when the City has implemented mandatory conservation measures. Under these MIFs, flowby can be reduced to 98.8 mgd from June 1 to November 30 and to 197.6 mgd from December 1 to May 30. These less stringent MIFs apply when water use conservation measures mandated in the VDEQ permit are instituted, i.e., when system water supply storage levels drop below certain specified levels.

In addition to the constraints on withdrawal imposed by the VDEQ permit MIFs, a pumping hiatus will be implemented during the spring spawning season during years of normal operation as a means of avoiding potential impacts to fish. This pumping hiatus is described in more detail below.

Because river flows vary naturally over both short and long terms in response to climatic changes, the amount of water withdrawn from the Mattaponi River will also vary over both the short and long terms. This variation would occur in response to changes in river flow as well as to changes in water demand, changes in reservoir capacity and the minimum flow requirements specified in the VDEQ permit that vary over the course of the year. To assess potential for impact to fish populations, it is necessary to estimate the levels of withdrawals most likely to occur, particularly during spawning periods for fish species of concern. Such estimation was done through water supply simulation modeling by Malcolm Pirnie, Inc., the RRWSG's engineering contractor for this project. Appendix F is a Technical Memorandum provided to the Panel by the City of Newport News and Malcolm Pirnie that summarizes the water supply simulation modeling methods and results. The Panel did not conduct an independent evaluation of the water supply modeling and thus accepts the modeling results as valid for use in the fish impact assessment.

Safe yield modeling of the proposed project was conducted using hydrologic data from the period October 1929 to September 1987[1] and anticipated 2040 to 2050 water demand conditions, together with the mandated minimum instream flow requirements. The specific instream flow constraints incorporated into the safe yield modeling varied in response to the modeled system storage levels.

Summary statistics on the anticipated withdrawals based on safe yield analysis on a seasonal basis are as shown in Table 2-2. Model results show that withdrawals will, on average, be less than 7.5 mgd more than half the time and less than 33.2 mgd 75 percent of the time. Average seasonal withdrawals range from 12 percent to 25 percent of the design capacity of the system (75 mgd), with median flows being 6 percent to 11 percent of capacity. The fact that the median (50^{th} percentile) withdrawal rates are substantially lower than the average rates demonstrates that in most years withdrawal will be at levels well below the overall average rates. These projected spring withdrawals do not take into account the spawning season pumping hiatus, which would last an average of about 60 days and reduce the average spring percentage by about two thirds.

Table 2-1. Minimum in-stream Mattaponi River flow-by (80 percent exceedance MIF) at Scotland Landing mandated by the VDEQ Water Protection Permit for the King William Reservoir project

Month	Minimum flow (million gallons per day)
January	329
February	423
March	434
April	347
May	206
June	115
July	115
August	114
September	114
October	114
November	125
December	231

[1] Two models used in these analyses used two different series of time series of data, one extending to 1987 and the other to 2002; see Appendix F for details.

Table 2-2. Predicted average water withdrawal amounts by season excluding the spring pumping hiatus period.

Season	Average	Median	Upper Quartile
Winter	16.2 mgd	5.2 mgd	22.5 mgd
Spring (spawning period pumping hiatus not incorporated)	13.2 mgd	8.0 mgd	10.4 mgd
Summer	9.1 mgd	4.7 mgd	7.5 mgd
Fall	19.6 mgd	7.3 mgd	33.2 mgd

The detailed modeling results presented in Appendix F illustrate the extent to which the VDEQ permit mandated MIFs constrain the extent of water withdrawal from the Mattaponi River in summer months. The significance of the MIFs is evident in Figure 2-5, in which the 80 percent exceedance and 40/20 Tennant MIFs are plotted together with average monthly flows at Scotland Landing for four different years. As is explained in Appendix F, these years follow years of drought conditions between 1929 and the present, and would represent years in which substantial water withdrawal would be desirable in order to refill the reservoir. This figure illustrates that in the four years for which data are plotted here, the average monthly river flows during summer months in each of those years fall consistently below the MIFs. Because the data plotted in the figure are monthly averages, some daily flows within a month may exceed the MIFs during portions of each of the summer months. Thus some withdrawals could occur. However, the data clearly suggest that summer withdrawals will be both limited and intermittent.

During the spring in years of normal operation, water withdrawal will not occur when early life stages of American shad that are vulnerable to entrainment or impingement (i.e., eggs and yolk-sac larvae) are present. Mattaponi River-specific temperature triggers will be established based on 8 or more years of intensive pre-operational monitoring of fish eggs and larvae abundance and distribution in the Mattaponi River, in conjunction with continuous temperature monitoring. The duration of a pumping hiatus in any given year is predicted to range from 44 to 83 days, and to average 61 days over the long term. The basis for selecting temperature as a trigger for pumping hiatus, the methodology to be used in selecting the triggers, the anticipated level of protection afforded by these triggers, and the design of a monitoring program which will provide the necessary data are summarized in Section 5, below, and presented in detail in Appendices C and D.

2.3.2 Drought Emergency Years

The spawning period pumping hiatus will not be implemented in years when a drought emergency declared by the State of Virginia is in effect in the spring. A Virginia Drought Assessment and Response Plan, prepared by a technical advisory committee in consultation with representatives from several State agencies, was submitted to the Assistant Secretary of Natural Resources on March 28, 2003. The plan established regions and protocols for monitoring and

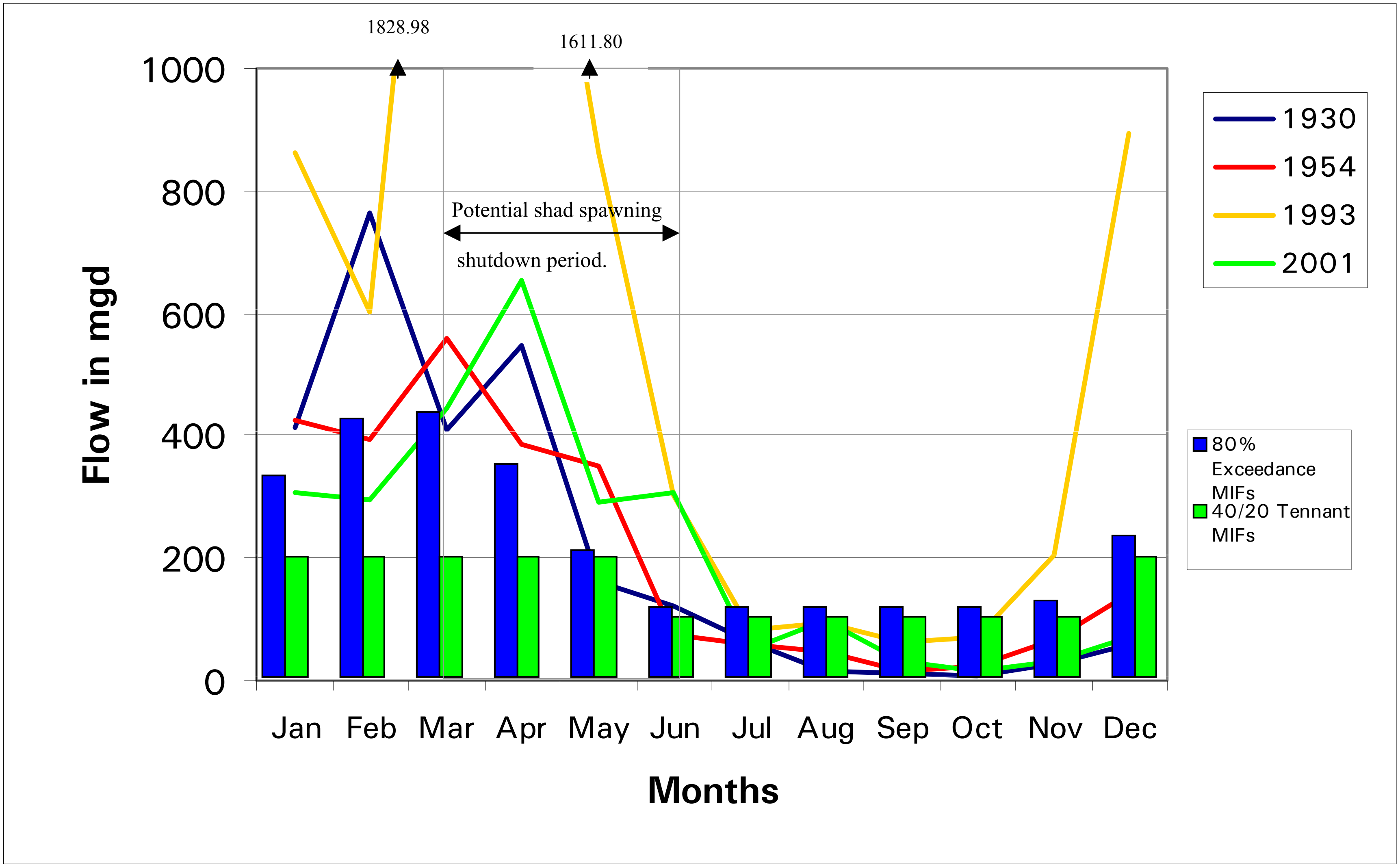

Figure 2-5. Estimated monthly freshwater flows at Scotland Landing for the years indicated, with mandated monthly minimum instream flows indicated.

managing water supply actions under varying water supply conditions. The Peninsula region uses the Newport News Reservoir System as one of the monitoring and trigger levels for actions in response to changes in system water supply. The type of action to be taken is specified in 4 levels or tiers, with emergency conditions being the highest or most severe level. The 60-day water supply level at which an emergency may be declared can vary between 30 percent and 40 percent of Newport News Reservoir System capacity, depending on the actual level of daily demand being experienced in the region.

The project as proposed does not include a KWR pumping hiatus during the spring spawning season under level 4 drought emergency conditions. It is assumed that the declaration of such an emergency would be made by the Governor of Virginia. Appendix F summarizes the safe yield analysis simulations that were run to determine the approximate probability of occurrence of severe drought conditions that would potentially lead to a drought emergency declaration over the period of record for which Mattaponi River flow data was available. Three extended or multi-year drought periods were identified between 1928 and 2002 during which simulated reservoir levels dropped below mandatory drought action trigger levels in the VDEQ permit during the shad spawning period. Only the spring months of 1931 and 1955 were within drought periods capable of depleting reservoir levels to VDEQ drought action trigger levels. Thus, for period of record, water withdrawal during the spring spawning season would have been allowable in 2 of 74 years, and thus be a low frequency event. RRWSG has indicated that these projections were based on model runs employing the 2040 water demand throughout the modeled time period. Current water demand is about two thirds of that level. At this lower demand, model runs show no drought emergency conditions in the 74 year projections. Thus, the probability of drought emergency declarations in the next 30 to 40 years would likely be lower than 2 in 74.

The latest published studies on climate change in the mid-Atlantic (USEPA 2001) predict that it will be somewhat warmer and perhaps wetter in the Mid-Atlantic Region in the future. They predict an increase in average stream flows but also a higher degree of variability in weather, with increased frequency and magnitude of floods and droughts. If the frequency and magnitude of droughts in the future increased, the frequency of drought emergencies might be higher that predicted from the 74-year period of record. However, this outcome was considered uncertain[2] and no projection of the probable magnitude of the increase in frequency or magnitude of future droughts is provided. Higher occurrence of floods would be likely to contribute to maintenance of high reservoir capacity values over time, a factor that might reduce the probability of a drought emergency being declared even during periods of reduced precipitation.

In years when a drought emergency is declared, water withdrawals can only be made in compliance with the MIFs discussed in Section 2.3.1, above. The only circumstances when spring withdrawals could be substantial would be when spring river flows would be well above

[2] Predictions in the Mid-Atlantic Regional Assessment report are categorized as “Most Certain,” “Moderately Certain,” and “Uncertain.”

the MIFs at the same time reservoir capacity would be below drought capacity levels specified in the VDEQ permit. In two modeled years in which a drought emergency in spring was likely to be declared, withdrawals were constrained by the MIFs in five of six spring months to 14 percent to 66 percent of design capacity (Table 2-3). Withdrawals at 100 percent of capacity in March 1955 are possible because river flows in that month were exceptionally high (630 mgd monthly average). Even at that high rate, withdrawal would represent only 12 percent of total freshwater flow. As is suggested from Figure 2-5, it is highly likely that mandated MIFs will preclude significant water withdrawal in summer and fall during for low flow years, which are likely to coincide with declaration of a drought emergency. Figures 8 through 11 in Appendix F provide additional illustrations of the impact of the MIFs on projected withdrawals.

Table 2-3. Safe yield-modeled projections of maximum withdrawals in spring months during drought emergency years (provided by Malcolm Pirnie, Inc.)

Month and Year	Maximum withdrawal (mgd)	Percent of design capacity
March, 1931	20.0	26.7
April, 1931	34.7	46.3
May 1931	41.0	54.7
March 1955	75.0	100.0
April 1955	49.5	66.0
May 1955	10.5	14.0

2.4 INTAKE SCREEN OPERATIONAL CHARACTERISTICS

The rate of water withdrawal establishes the through-slot velocity of water passing from the river into the KWR intake wedgewire screens. This through-slot velocity, in combination with slot dimensions and mobility of the life stages, in turn establishes what fish life stages may be vulnerable to being impinged on the screens or entrained through the screens, and thus lost to the ecosystem. The through-slot velocity also establishes the zone of influence of the intake within the water column, and thus what portion of vulnerable life stages within the water column may be subject to intake effects. Based on the estimates of expected average seasonal water withdrawals presented in Table 2-2, the estimated seasonal through-slot velocities for the KWR intake are presented in Table 2-4. Since the figures in this table are based on the predicted seasonal withdrawal rates presented in Table 2-2, they also do not reflect the effect of the spring pumping hiatus, which would result in zero through-slot velocity in the spring.

Through-slot velocities are estimated to be in the range of 10 percent or less of the design value (0.25 fps) half of the time and less than 0.1 fps 75 percent of the time. Of greatest relevance are the estimated through-slot velocities for the spring (spawning) period. These estimated low through-slot velocities were taken into account in the Panel's assessment of potential for entrainment and impingement of vulnerable Mattaponi River fish life stages when pumping may occur during the spawning season under drought emergency conditions, as will be discussed in Section 5. An additional factor that influences the interactions of fish early life stages with the screen face is the "sweep velocity" of water passing across the screen face and its magnitude relative to the through-slot velocity. Given the configuration of the intake screens (Figure 2-1), tidal flows will generate the significant sweep velocities. Details of how through-slot velocities, sweep velocities, and tidal transport past the intake screens affect potential for entrainment and impingement are presented in Appendix E and in Section 5.

Table 2-4. Estimated seasonal through-slot velocities at the KWR intake screens.

Season	Average	Median	Upper Quartile
Winter	0.05 fps	0.02 fps	0.08 fps
Spring	0.04 fps	0.03 fps	0.03 fps
Summer	0.03 fps	0.02 fps	0.02 fps
Fall	0.07 fps	0.02 fps	0.11 fps

2.5 OTHER VDEQ PERMIT WATER INTAKE OPERATING CONSTRAINTS

In addition to the MIFs specified in the VDEQ Virginia Water Protection Permit for KWR noted above, there are also requirements for development of an ecosystem monitoring program and a program to monitor salinity within the tidal freshwater portion of the Mattaponi River. Those monitoring programs are to be developed with input from all project stakeholders. One stated objective of the monitoring programs is to detect any salinity-induced changes to the location of spawning and nursery grounds used by anadromous fish. Section D.7 of the permit specifies that, "the conditions of this permit may be modified should the ecomonitoring or salinity monitoring plan results document ecological problems attributable to the withdrawal of water from the Mattaponi River." Thus, the results of monitoring during facility operation could result in additional changes in intake operation.

3.0 THE MATTAPONI RIVER ECOSYSTEM

This description of the Mattaponi River ecosystem is very brief and addresses only those attributes of the ecosystem that are pertinent to the Panel's assessment of potential impacts on fish and on mitigation measures. Much more extensive characterizations of the ecosystem are presented in prior assessment reports identified in Appendix B and included in references of this report.

3.1 PHYSIOGRAPHY

The Mattaponi River is a lowland coastal river draining the Coastal Plain province of central Virginia (Figure 3-1). It is formed by the confluence of three tributaries, the Matta, the Po and the Ni Rivers in Caroline County, and flows generally southeast to empty into the York River at West Point. The Mattaponi consists of an upper free-flowing section and a lower tidal section. The division between the tidal and non-tidal sections of the River occurs at the fall line, just upstream of Aylett, approximately 41 miles upstream of West Point. The non-tidal Mattaponi is a classic low gradient stream with extensive meanders and forested wetlands. It is approximately 44 miles long and drains a watershed of approximately 620 square miles (Brooks 1983). Surrounding land use in the upper Mattaponi is primarily forested and agricultural (Bilkovic 2000).

The Mattaponi joins the Pamunkey River at West Point to form the York River, which then empties into Chesapeake Bay estuary (Figure 3-2). The tidal Mattaponi, together with the tidal Pamunkey River and the York River, are known as the greater York subestuary. The tidal Mattaponi River is approximately 41 miles long and drains an additional watershed of approximately 300 square miles (Brooks 1983). The York River, into which the Mattaponi River discharges, extends another 30 miles to join Chesapeake Bay at Gloucester Point, Virginia.

The upper tidal Mattaponi is relatively shallow with maximum depths generally less than 10 feet. South of Walkerton (RM 29), the riverbed alternates between shallow and deep areas with shallow areas ranging from 10 to 15 feet deep and deeper areas averaging from 20 to 30 feet deep (Figure 3-3). Cross-sectional area of the tidal river gradually increases moving downstream as the river both widens and deepens. The tidal Mattaponi is surrounded by extensive wetlands in many areas and there are no major tributaries draining into this section of the river. The tidal Mattaponi River has a total water surface area of 6.3 square miles and a total volume of 16,458 million gallons at mean low water (Brooks 1983). Most of the tidal volume is located near the lower end of the River; less than 15 percent of this volume is located upstream of Scotland Landing.

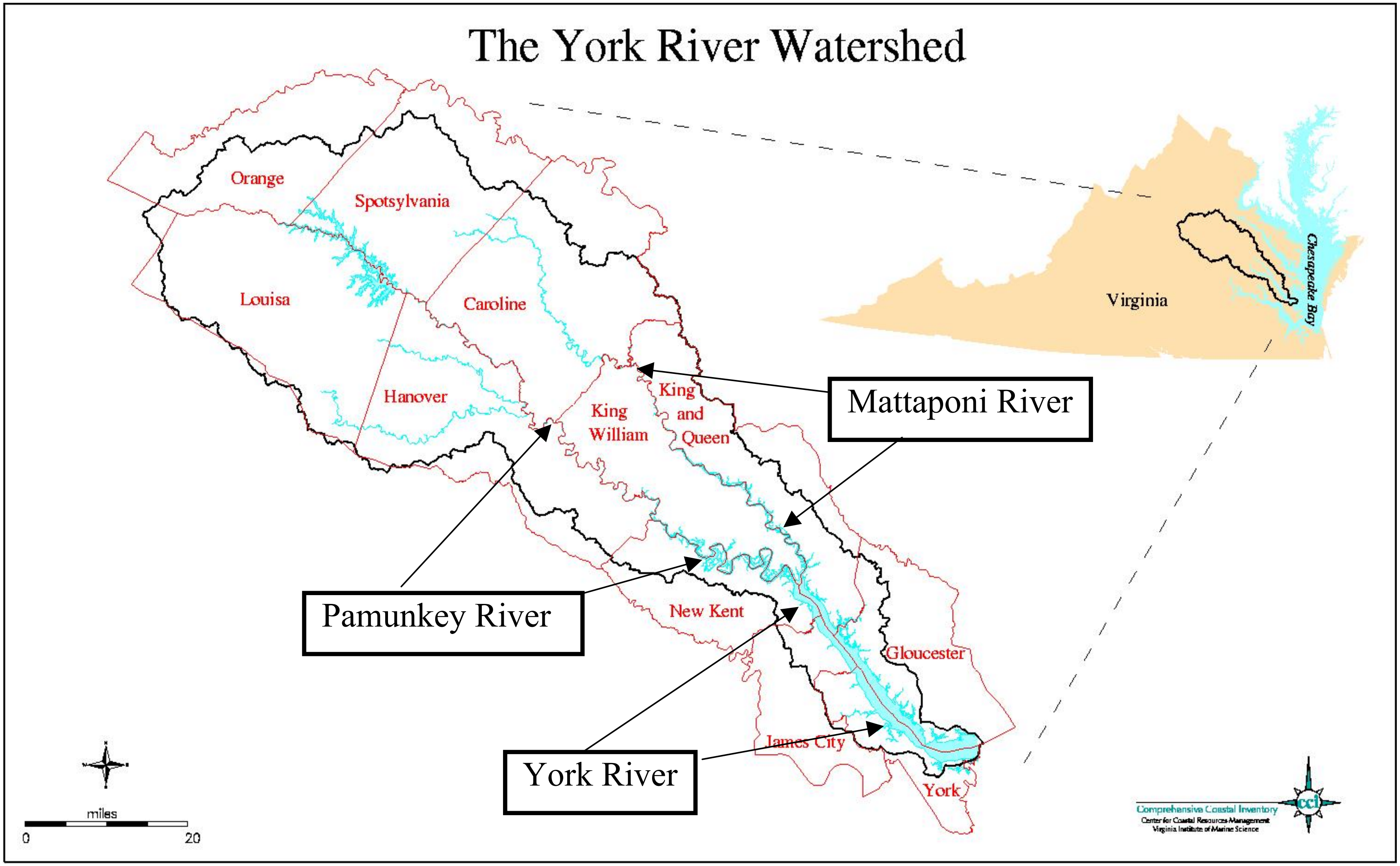

Figure 3-1. The York River watershed.

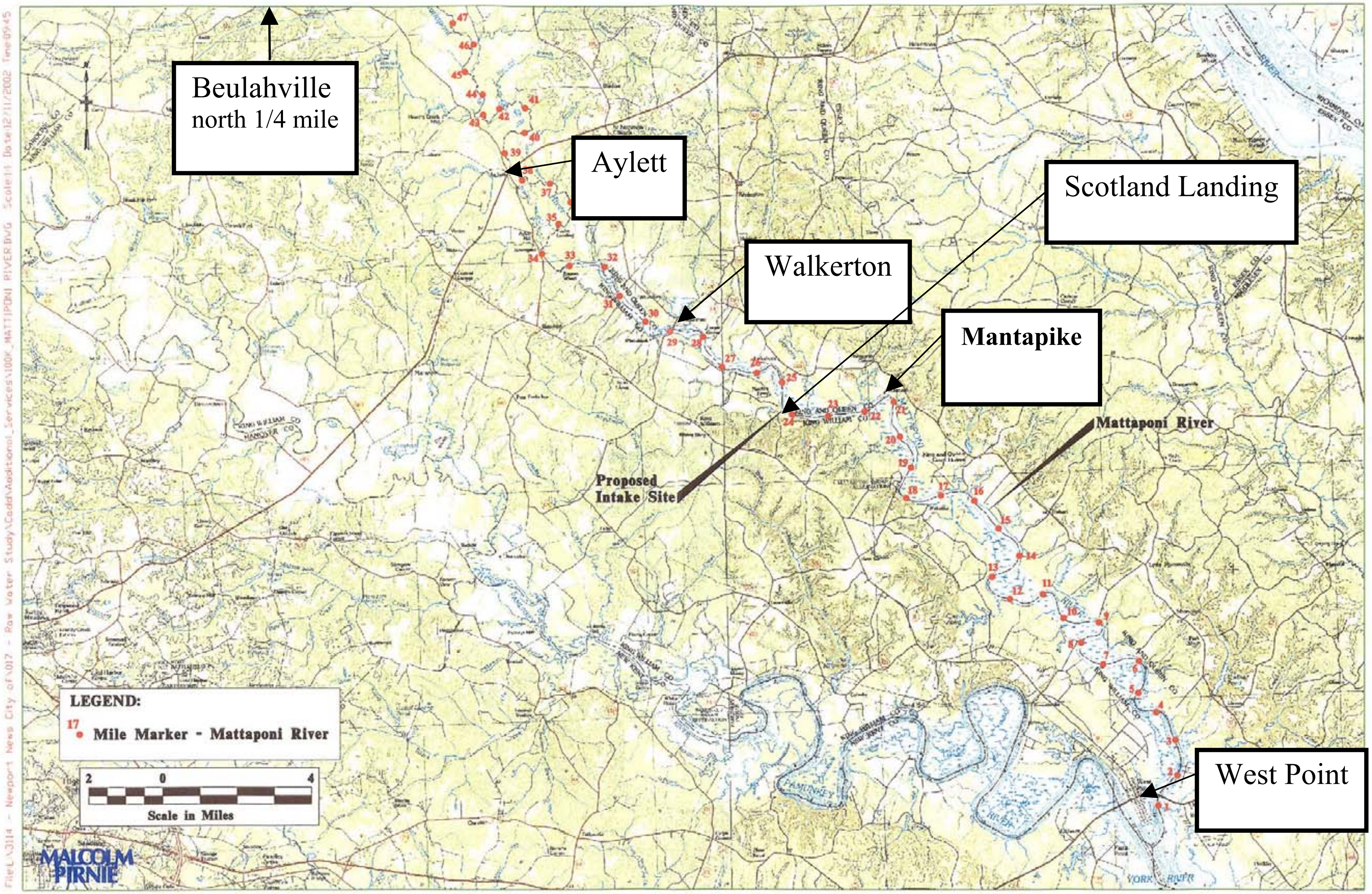

Figure 3-2. Proposed location of the KWR water intake in the Mattaponi River.

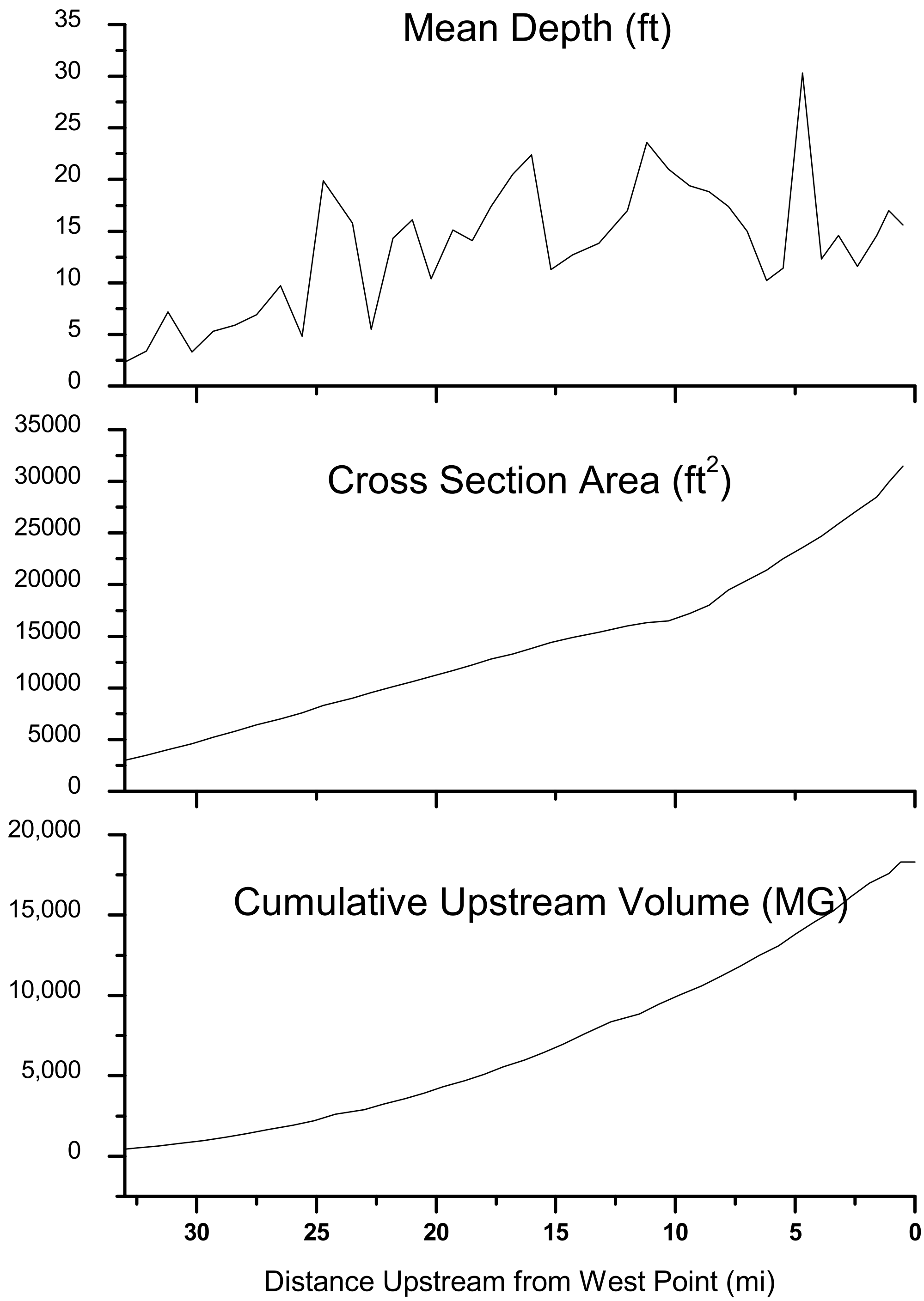

Figure 3-3. Bathymetric characteristics of the Mattaponi River.

3.2 HYDROLOGY

3.2.1 Freshwater inflow

Freshwater flows in the non-tidal section of the Mattaponi River have been monitored at the USGS gauging station near Beulahville, Virginia since 1941. They exhibit a seasonal pattern typical of most temperate estuaries, with higher flows in the later winter and spring and lower flows during later summer and early fall (Figure 3-4). Highest daily flow within the time period record used in safe yield modeling was 10,470 mgd on 25 June 1972 (Hurricane Agnes) while the lowest flow within that time period was 0.5 mgd on 13 August 1999. The lowest flow ever recorded for the Mattaponi River was 0.26 mgd in August 2002.

The KWR intake is located at Scotland Landing, approximately 48 km downstream of Beulahville. Freshwater flows at Scotland Landing are higher than at Beulahville as a result of the total watershed being approximately 30 percent larger at Scotland Landing. The safe yield modeling work conducted by the City included estimation of Scotland Landing flows. VDEQ water withdrawal permit restrictions are based on flows at Scotland Landing.

3.2.2 Tides and Tidal Currents

The Mattaponi River experiences tidal cycles typical of most Atlantic coastal estuaries, having two high tides and two low tides each day. The time between successive high and low tides is approximately 6.5 hours. Tides progress up the Mattaponi with slack tide occurring at the upper end of the tidal river approximately 4 to 5 hours later than those observed at West Point. Owing to the narrowing of the River, tidal amplitude increases from an average of 3 feet at West Point to an average of almost 4 feet at Walkerton. Tidal fluctuation at Scotland Landing is approximately 3.5 feet, and maximum tidal velocities at that location range from 2.5 to 2.9 fps. Tidal velocities are of significance to potential for impact since they provide the "sweep velocities" of water across the wedgewire screen face.

The maximum excursion of water within the river over a tidal cycle is a function of tidal velocities and available cross-sectional areas. Maximum tidal excursion within the Mattaponi is highest (3 to 5 miles) in the upper tidal reaches where the River is relatively shallow and narrow (Figure 3-5). The tidal excursion decreases rapidly downstream through Walkerton where it averages 2 to 2.5 miles. Further downstream the tidal excursion again increases to almost 4 miles at Heartquake Creek (RM 10) and then declines to 2.5 miles at West Point. The magnitude of this tidal excursion is directly proportional to tidal velocity; areas of high tidal excursion also have high tidal velocities. The magnitude of the tidal excursion is one factor establishing what proportion of a total population of planktonic organisms within the Mattaponi River may be vulnerable to impacts from the water intake. Because net tidal movement is downstream, organisms located more than one tidal excursion distance downstream of the intake will not be

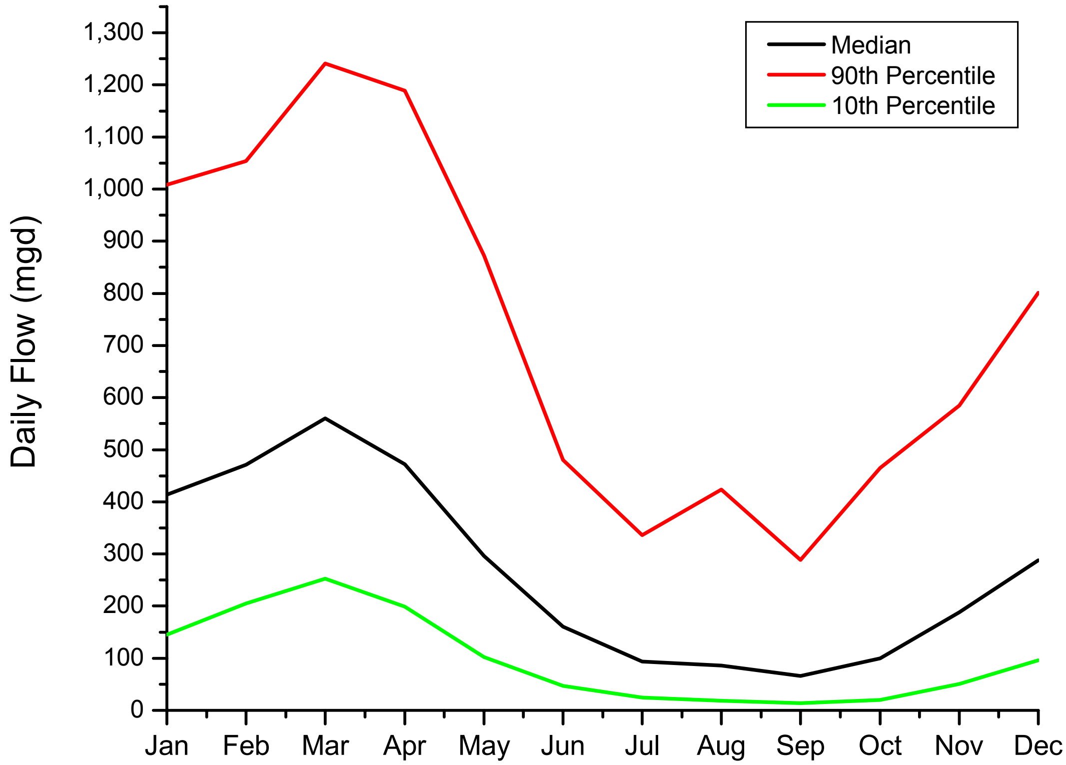

Figure 3-4. Mattaponi River freshwater flows as recorded at the USGS Beulahville gauging station.

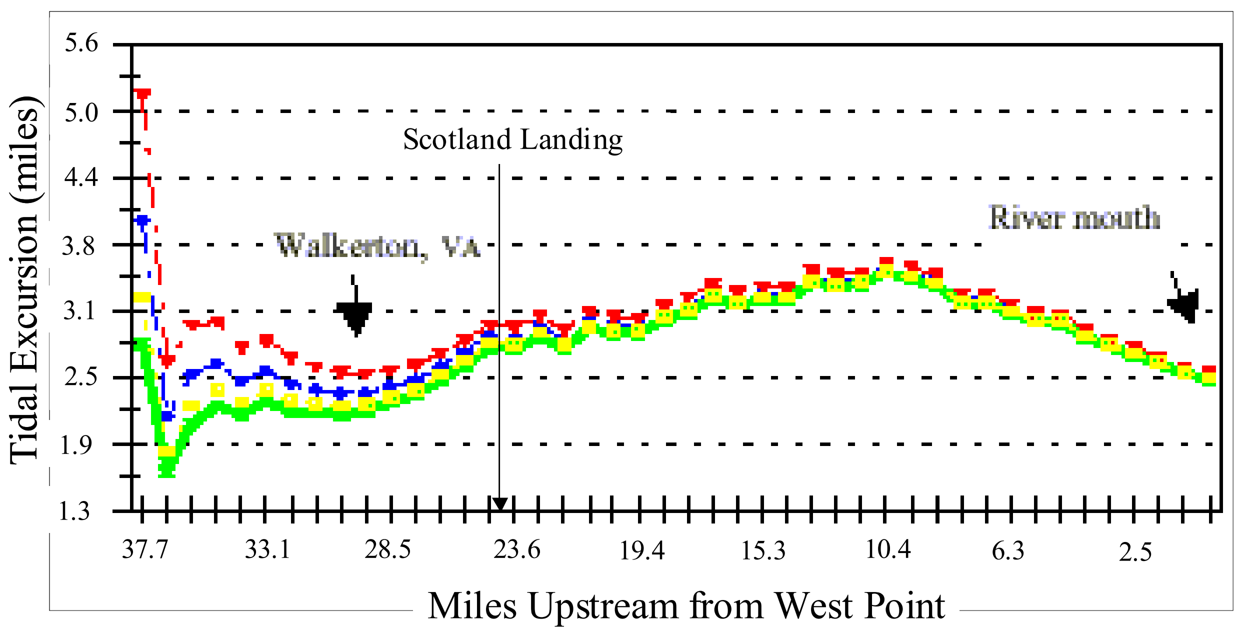

Figure 3-5. Tidal excursion distances as a function of location within the Mattaponi River

transported past the intake on flood tides, and will be displaced further downstream on each successive tidal cycle. They will thus not be exposed to water withdrawal effects.

3.3 SALINITY

As previously described, the tidal Mattaponi is part of the greater York subestuary to Chesapeake Bay. Within this system, freshwater flows are gradually mixed with the more saline waters of the Chesapeake Bay. The location of the transition between fresh and brackish waters varies depending on the volume of freshwater entering from upstream. For much of the year, most of the tidal Mattaponi River is freshwater. However, during low flow periods (typically late summer and fall) brackish waters can enter into the lower tidal Mattaponi. During extreme low flow events, this brackish water can extend as far upstream as Courthouse Landing (RM 18) or even farther. On the other hand, during rainy summers, the Mattaponi can remain exclusively freshwater throughout the year.

Field surveys of salinity within the lower Mattaponi River (Brooks 1983) reveal that brackish waters with a salt content of 5 parts per thousand (ppt) rarely intrudes more than 10 miles upstream of West Point. For the most part, areas upstream of Davis Beach (RM 15) remain exclusively freshwater throughout the year. At issue is whether water withdrawals would result in encroachment of saline waters farther up the Mattaponi, altering the salinity characteristics of habitats there, and whether salinity changes of the magnitude predicted would adversely affect any vulnerable life stages of any species of concern.

3.4 WATER QUALITY

There are currently no major municipal or industrial discharges into the Mattaponi River basin and no point source discharges of any kind in the vicinity of the proposed intake. However, there is a growing concern about nutrient input within the tributaries to the York River, principally through non-point sources (VSNR 2000). Currently, the lower Mattaponi River (Clifton to West Point) and the entire York River downstream are listed as nutrient enriched. Recent water quality monitoring reveals improving trends for nitrogen and phosphorous, which are the two nutrients of greatest concern (Langland et al. 2001). These concerns have led to efforts to reduce such enrichment through nutrient reduction strategies (VSNR 2000). Currently, the upper Mattaponi River barely meets habitat objectives for submerged aquatic vegetation for phosphorous and available light. The lower Mattaponi River fails to meet these objectives for available light and suspended solids, and is borderline for phosphorus and phytoplankton. There are no water quality issues associated with the KWR water intake.

3.5 THE AQUATIC ECOSYSTEM

The Mattaponi River provides a wide variety of aquatic habitats that support a diverse biological community. In the upper, non-tidal Mattaponi River, aquatic habitats include the free-flowing stream and tributaries, slow moving backwater areas, and surrounding non-tidal wetlands. The tidal Mattaponi River provides additional habitat types, including shallows and deeper channel areas, tributaries, and surrounding tidal wetlands. The tidal Mattaponi River, and the greater York River subestuary of which it is a part, contain a diverse biological community comprised of thousands of individual species as a result of the salinity gradient ranging from fresh to mesohaline and the habitat diversity described above. The portion of the river within a tidal excursion distance of the proposed KWR intake location supports tidal-freshwater and oligohaline aquatic communities similar to those found throughout the Chesapeake Bay's major tributaries.

4.0 MATTAPONI RIVER FISH COMMUNITY AND IDENTIFICATION OF SPECIES VULNERABLE TO POTENTIAL KWR WATER INTAKE EFFECTS

4.1 COMMUNITY COMPOSITION

The fish community in the tidal Mattaponi River is typical of similar lowland streams and rivers in the mid-Atlantic region and throughout the Chesapeake Bay. Thirty-five fish species have been documented as being present in the Mattaponi River in the vicinity of the proposed intake location at Scotland Landing based on electro-fishing sampling programs (Dowling 1994; VDGIF, pers. comm.) or are known or believed to occur within tidal, freshwater reaches of Chesapeake Bay tributaries in Virginia such as the Mattaponi (Jenkins and Burkhead, 1994) (Table 4-1). This community assemblage includes 24 year-round resident, freshwater species, 10 diadromous and semi-migratory species, and one estuarine-dependent species. Numerically dominant species in VDGIF samples were generally resident freshwater species such as redbreast sunfish (Dowling 1994).

Table 4-1. Fish species present in the Mattaponi River in the vicinity of the KWR intake at Scotland Landing their exposure to KWR effects

Life History Category	Species	Potentially Exposed Life Stages And Their Seasonal Exposure	
Anadromous/ Semi- Migratory	Sea lamprey Atlantic sturgeon Blueback herring Alewife American shad Hickory shad Striped bass White perch Yellow perch	Adults Early life stages Juveniles	Spring Spring Summer/Fall
Catadromous	American eel	Juveniles (glass eel, elver) Sub-adult	Spring All seasons
Estuarine Dependent	Bay anchovy	All	All seasons
Resident	Longnose gar Gizzard shad Satinfin shiner Spottail shiner White catfish Blue catfish Inland silverside Banded killifish Redbreast sunfish Pumpkinseed Redear sunfish Largemouth bass Bowfin Common carp Eastern silvery minnow Shorthead redhorse Channel catfish Brown bullhead Tessellated darter Eastern mosquitofish Bluegill Bluespotted sunfish Black crappie Walleye	All	All

The exposure of individual fish species to potential effects of the water intake varies as a result of their different life history characteristics. Resident species are present in the Mattaponi River year around and complete their entire life cycle within the river, although not necessarily within the area of influence of the KWR intake. Any life stage of resident species that might occur in the vicinity of the intake in any season could potentially be affected by water withdrawal. Anadromous alosine species (American and hickory shad, blueback herring, alewife) migrate into tidal and non-tidal fresh waters to spawn in the spring, with surviving adults returning to the ocean after spawning and early life stages and juveniles utilizing the tidal freshwaters as nursery grounds until migrating seaward in the late summer and fall (Funderburk et al, 1991). Adults of other anadromous species (striped bass, Atlantic sturgeon, sea lamprey) make spring spawning migrations similar to alosines, but juveniles of these species may spend several years in estuarine or fresh waters before migrating to the ocean (Funderburk et al, 1991; Bigelow and Schroeder, 1953). The single catadromous species, American eel, spawns in the Atlantic Ocean, with juveniles (glass eels, elvers) migrating into estuarine and fresh waters in the spring and early summer, where they may remain until reaching sexual maturity, which is usually from 15 to 24 years (Haro et al., 2002). Semi-migratory species (white perch, yellow perch), make spawning migrations into suitable spawning areas within tidal freshwaters, and then migrate to seasonal habitats while remaining for their entire life cycle within estuarine waters (Richkus and Stroup, 1987a,b). The single estuarine dependent species, bay anchovy, lives its entire life cycle in estuarine waters, with only marginal use of tidal freshwater habitats by juvenile stages. Detailed descriptions of the life histories of many of these species and the status of Mattaponi River fish populations that are exploited are presented in other reports (e.g., ASA 2003; Mann 2003) and are not duplicated here.

During the summer months, it is likely that the lower Mattaponi River also provides nursery habitat for a variety of juveniles of amphidromous[3] species, such as spot, Atlantic croaker, and Atlantic menhaden. These species are common inhabitants of Chesapeake Bay and can be seasonally abundant in Bay waters. However, their salinity requirements likely limit their distribution to the brackish waters of the lower Mattaponi. None of these species were reported in the results of electrofishing surveys at Scotland Landing conducted by the VDGIF .

4.2 SPECIES VULNERABILITY TO POTENTIAL MODES OF IMPACT

As briefly noted in the Section 1.0, above, and as will be discussed in more detail in Section 5.0, below, potential modes of impact to fish populations from the KWR water intake include: construction (e.g., physical changes to the environment, turbidity); impingement (i.e., trapping of fish on intake screens and consequent mortality during water withdrawal); entrainment (i.e., passage of early life stages through intake screens and their loss to the ecosystem during water withdrawal); salinity changes (e.g., habitat changes that could adversely affect the use of that habitat by fish populations); and noise (e.g., any anthropogenic sounds produced by the water intake when operating that could alter normal fish behavior). Each of

[3] Amphidromous species migrate from freshwater to the sea and vice versa but not for breeding

these potential impact modes will be described here in order to identify those members of the fish community that could potentially be vulnerable to intake effects. The species and life stages identified as being potentially vulnerable are the focus of the assessments presented in Section 5.

4.2.1 Vulnerability to Construction Impacts

Construction is prohibited between February 15 and June 30, which completely encompasses the majority of the spawning period for all anadromous and most resident species that inhabit the Mattaponi River. Thus, impacts to most early life stages of these spring-spawning species as a result of construction activities cannot occur. Early life stages of species such as bay anchovy, that spawn into the summer months, could be exposed to effects of construction activity. The RRWSG's engineering contractor, Malcolm Pirnie, indicated that in-river construction will take 6 months or more, so some activity is likely to be on-going through the summer, fall and winter. Thus, the life stages and species potentially exposed to impacts would include juvenile anadromous fish and all life stages of all other species that may occur in the Scotland Landing area of the Mattaponi. From a long-term perspective, the construction of the KWR intake results in permanent placement of a large physical structure in the water column, and some changes in substrate, as described in Section 2.2. All species and life stages that occur in the Mattaponi River would be subject to any effects resulting from those habitat changes

4.2.2 Vulnerability of All Life Stages to Impingement Impacts

Impingement occurs when aquatic organisms are trapped (impinged) against the intake screens or related structures at the entrance of a facility's water withdrawal intake by the velocity of the intake flow. This occurs when the intake velocities exceed the swimming speed of the organism. Aquatic organisms trapped on the screen may die of exhaustion, suffocation or other injuries (Nagle and Morgan 2000). Impingement is of particular concern at facilities that withdraw large volumes of water for cooling purposes, such as power generating facilities, and has been extensively studied at such facilities throughout the United States (e.g., Wisniewski, 2000). However, volumes of water withdrawn at such facilities and velocity of water as it passes through their protective screens are much higher than what will occur at the KWR wedgewire screens. In guidelines for the power industry for best available technology for minimizing impacts to fish, Boreman (1977) suggested the criterion for minimizing impingement impact potential was through-screen velocities less than 0.5 ft/sec, a criterion which has been adopted and maintained in USEPA's new Clean Water Act Section 316(b) rules. Extensive laboratory and real-world experience with low through-screen velocity screening technology has demonstrated that impingement of larger aquatic organisms (those greater than about 1 inch [25.4 mm] long) is virtually eliminated by low (<0.5 fps) through-slot velocities (e.g., Veneziale 1992; Zeitoun et al 1981). The USEPA-recommended criterion is double the design maximum through-slot velocity for the KWR intake screens. Furthermore, many of the general findings regarding protective value of these higher through-screen velocities are for conventional flat screens, with all flow passing through the screen. Such screens pose greater risk for impingement and impingement mortality than cylindrical screens aligned parallel to river flow as proposed for the Mattaponi intake.

The USEPA concluded that cylindrical wedgewire screens are an effective technology for substantially reducing the impingement of aquatic organisms, with reductions of up to 99 percent over conventional intake screens (USEPA 2002). This conclusion is supported by experiences with similar intake structures operating within nursery habitats of many species (e.g., Ehrler and Raifsnider 1999; Lifton 1979).[4] As will be discussed in detail in Section 5 and Appendix E, wedgewire screens of the type proposed for the KWR intake have a number of attributes in addition to low through-slot velocities that significantly reduce or eliminate potential for impingement. These additional attributes include small mesh, high sweep velocities, and mid-water location. The benefits of each of these attributes will be discussed in detail below.

The swimming speed of fish varies by species and by size within species, and two types of speeds commonly documented in experimental studies are burst speed and sustained speed (Videler 1993). Another term used is critical speed, which is a speed that can be maintained for a specified period of time (Gowan et al, 1999). Sustained swimming speeds of fish are particularly important relative to impingement in circumstances such as intake embayments, where fish are restricted to an area immediately in front of an intake screen and may swim until becoming fatigued and falling back onto the screen when the water velocity exceeds their sustained swimming speed capability. Because the KWR intake screens are cylindrical, suspended vertically in the water column, and subject to nearly continual tidal flows across the screen face, fish will not be constrained such that they would have to continuously swim against intake screen intake flows. Thus, sustained swimming speeds are of lesser importance to impingement assessment in this instance and would be of significance only during the relatively short slack tide periods when sweep velocities may be lower than through-slot velocities. Burst speeds are those exhibited when fish encounter an object, such as an intake screen, or perceive a threat (e.g., from a predator), and move rapidly away. Burst speeds are not sustainable for more than very brief time periods. Burst speeds are likely to be of greater relevance than sustained swimming speeds to potential for impingement at the KWR intake screen when high sweep velocities are occurring.

Figure 4-1 presents fish swimming speeds relative to body length for a wide range of species of varying sizes (note that the graph is in log:log scale). The smallest fish for which data are presented in this figure are on the order of 3 cm (1.2 in) in length, with swimming speeds on the order of 63 cm/sec (approximately 2 ft/sec). Thus, the data shown do not include swimming speeds of any larval fish. This graph, while including data from a wide range of fish species and

[4] The majority of studies of effectiveness of different screening technologies has been funded by industry, particularly the power generation industry, in order to evaluate the effectiveness of those technologies for use at their facilities to meet regulatory requirements. Very few intake technology papers have appeared in peer-review journals. However, studies published in many proceedings of symposia dealing with screening issues have been subjected to peer review. For example, EPRI-sponsored publications typically require two outside peer reviews of each contribution (D. Dixon, EPRI, pers. comm.).

sizes not native to Chesapeake Bay waters, illustrates several general relationships between fish size and fish speeds. All swimming speeds are consistently greater than a body length per second, and burst speeds tend to be about 10 times sustained swimming speeds for most species and sizes. The data also illustrate that all fish greater than 3 cm in length for which data are plotted have swimming speeds many times greater than the maximum KWR slot velocities of 0.25 fps.

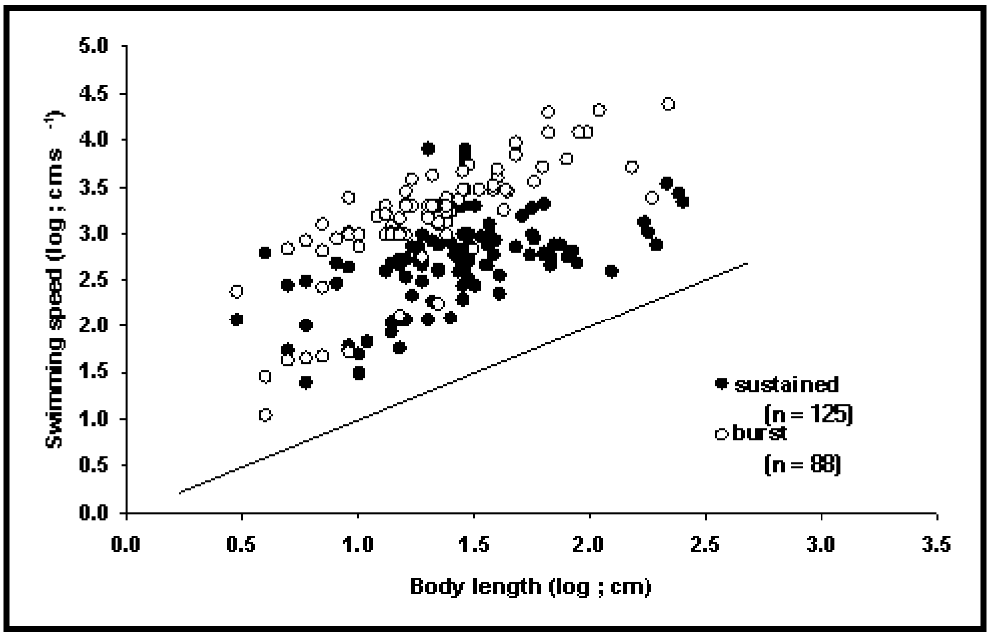

Figure 4-1. Relationship between swimming speed and body length of fishes (from http://www.fishbase.org/manual/FishbaseThe_SWIMMING_and_SPEED_Tables.htm). Note that both the axes are log scale.

Data on swimming speeds of larval fish are more limited than data for juvenile and adult life stages. Table 4-2 presents larval burst swimming speeds for three marine species, one of which is herring, a species related to American shad and river herring. For herring larvae averaging about 10 mm in length, mean burst swimming speeds were about 0.2 fps (61 mm/sec). Initial flexion of the body for herring larvae resulted in movement of about 1 body length in 80 milliseconds, with somewhat lower speeds exhibited in subsequent milliseconds. Yin and Blaxter (1987) also reported that escape movements were not directional until the post-yolk sac larval stage, which would constrain the likelihood that yolk-sac larvae escape movements would always result in displacement of the larvae away from the screen face. Note that these swimming speeds were recorded for larvae experiencing starvation, so normal larvae may be capable of higher speeds. Gowan et al (1999) present additional data on critical swimming speeds of larvae of twelve species that were taken into account in their recommendation of 0.25 fps as a design criteria for through-slot velocities of intake screens. However, that recommendation also takes into account engineering constraints on achieving lower velocities.

Table 4-2. *Clupea harengus*, *Gadus morhua* and *Platichthys flesus* larvae maximum and mean speeds (ft s^{-1}) during starvation (body lengths per second, BLs^{-1}, given in parentheses). Speeds are means ± 95% confidence limits. "Probe" and "Pipette" were two different devices used for stimulating escape. (Converted from Yin and Blaxter 1987.) (Table taken from Henderson and Seaby, 2000.)

	Probe		**Pipette**	
	Max	**mean**	**max**	**mean**
Yolk-sac larvae				
Clyde herring	0.443 ± 0.069	0.217 ± 0.062	0.499 ± 0.043	0.24 ± 0.033
	(13.2 ± 2.1)	(6.5 ± 1.9)	(14.9 ± 1.3)	(7.2 ± 1.0)
Baltic herring	0.423 ± 0.039	0.197 ± 0.013	0.456 ± 0.043	0.203 ± 0.033
	(14.9 ± 1.4)	(6.9 ± 0.8)	(16.1 ± 1.5)	(7.5 ± 1.2)
Cod	0.226 ± 0.023	0.118 ±0.016	0.262 ± 0.026	0.141 ± 0.016
	(13.2 ± 1.3)	(7.2 ± 1.0)	(15.1 ± 1.5)	(8.6 ± 1.0)
Flounder	0.184 ± 0.03	0.098 ± 0.02	0.213 ± 0.049	0.115 ± 0.03
	(13.0 ± 2.1)	(6.9 ± 1.4)	(15.1 ± 3.5)	(8.1 ± 2.1)
Older larvae	Clyde herring			
36 d-old	0.577 ± 0.135	0.269 ± 0.075	0.643 ± 0.079	0.328 ± 0.046
	(12.1 ± 2.8)	(5.7 ± 1.6)	(13.5 ± 1.6)	(6.9 ± 1.0)
60 d-old	0.81 ± 0.161	0.417 ± 0.095	0.84 ± 0.128	0.476 ± 0.049
	(13.0 ± 2.6)	(6.7 ± 1.5)	(13.5 ± 2.0)	(7.6 ± 0.8)

While the maximum design through-slot velocity of the KWR intake screens is 0.25 ft/sec (76 mm/sec), through-slot velocities of less than 0.1 ft/sec (30.5 mm/sec) are expected to occur at least 75 percent of the time (see Table 2-4). At a burst speed of 6 times body length, the mean for herring larvae in Table 4-2, fish as small as 13 mm would be capable of avoiding impingement at the maximum through-slot velocity, with even smaller fish being capable of avoidance at the predominant 0.1 ft/sec through-slot velocity. This would occur even if they encountered the screen with no sweep velocities, as would occur near and during brief slack tide periods. The literature cited above confirms that only very small fish (only larval stages for large species such as American shad and striped bass but including juveniles of some small species such as silversides and bay anchovy), would be potentially susceptible to impingement at the KWR intake screens even at the maximum through-slot velocities. The same literature also supports the conclusion that juvenile and adult life stages of all fish species would not be vulnerable to impingement by the KWR intake. Those species whose earliest life stages may occur in the vicinity of the KWR intake screens and thus be susceptible to both impingement and entrainment are identified in the following section.

4.2.3 Vulnerability to Entrainment and Impingement of Early Life Stages

Only organisms small and flexible enough to be drawn through the 1-mm slots of the KWR wedgewire intake screens and with insufficient motility to escape from intake velocities would be vulnerable to entrainment. The larger organisms within this group would also be the most susceptible to impingement, if they were too large to pass through the 1-mm screen slot but did not have sufficient swimming ability to avoid contact with the screen. Later early life stages (e.g., post-yolk-sac stages of species with larger larvae), juveniles and adults are not susceptible to entrainment, and species with eggs too large to pass through the screen are also not vulnerable. Among the early life stages of the species that spawn in the Mattaponi River, the location and type of spawning, the size of the eggs and larvae, and the behavior of the motile early life stages are all factors that establish their vulnerability.

Although the American shad has been a primary focus of efforts to evaluate potential effects on fish of the proposed project, other migratory and resident fishes that occur in the vicinity of the intake site could also be vulnerable to entrainment effects. In an effort to systematically assess the vulnerability to entrainment effects of the fish species that comprise the Mattaponi River fish community assemblage, biological and ecological attributes were evaluated for 35 resident and migratory species. The assemblage includes 24 year-round resident, freshwater species, 10 diadromous and semi-migratory species, and one estuarine-dependent species. Each of the 35 species has been documented by recent boat electrofishing collections in the vicinity of the proposed intake (VDGIF, unpublished data) or is known or expected to occur within the tidal, freshwater reaches of the Mattaponi river mainstem (Jenkins and Burkhead, 1994). Several amphidromous species (e.g., Atlantic menhaden) that are collected occasionally in the vicinity of the proposed intake site were not included in the analysis. Similarly, fishes that may occur in the drainage, but are generally restricted to smaller tributaries than the Mattaponi River, were not included in the analysis.

The biological and ecological attributes of a species' reproductive behavior are of greatest relevance to the vulnerability of their early life stages to entrainment and impingement impacts. To systematically characterize their potential vulnerability, information on the spawning biology of each species (reviewed by Gowan et al, 1999) was used. Vulnerability scores of 1, 3, or 5, were assigned to each species for each of the six most relevant spawning attributes, based on literature information, data available for the Mattaponi River (e.g., VDGIF survey data) and Panel members' knowledge and expertise (Table 4-3), as will be explained further below. Where data were not available, an intermediate score of '3' was assigned. Where an attribute was not applicable for a particular species (e.g., American eel spawning occurs in the ocean and eggs and larvae would never be present in the Mattaponi River), a score of zero was assigned. Scores were assigned based on the minimum value for a given attribute and all attributes were weighted equally. The sum of scores provides a means of ranking species according to their relative vulnerability and thus establishes which species should be the focus of the Panel's assessment efforts. The rankings of species reflect vulnerability to entrainment and impingement relative to the other species in the analysis; rankings do not necessarily reflect the significance to the population of intake effects.

Table 4-3. Spawning attributes and scoring criteria for entrainment vulnerability assessment of resident and migratory fishes found in the Mattaponi River, Virginia. Where data were unavailable, the attribute was given an intermediate score of '3.' Where an attribute was not applicable to a particular species, a score of zero was assigned.

Metric	Scoring Criteria
Egg diameter (mm)	
High (5)	<1.0
Moderate (3)	1.0-2.0
Low (1)	>2.0
Pro-larvae length (mm)	
High (5)	<4.0
Moderate (3)	4.0-6.0
Low (1)	>6.0
Post-larvae length (mm)	
High (5)	<7.0*
Moderate (3)	7.0-10.0
Low (1)	>10.0
Egg distribution	
High (5)	buoyant
Moderate (3)	demersal/semi-demersal
Low (1)	benthic
Reproductive guild	
High (5)	broadcaster
Moderate (3)	substrate/crevice
Low (1)	nester/livebearer
Reproductive Habitat	
High (5)	obligate river spawner
Moderate (3)	facultative river spawner
Low (1)	non-riverine spawner

* Note that the scores of 5, 3 and 1 are relative within a metric; thus, while post-larvae < 7 mm are at highest risk within this life stage, pro-larvae >6 mm are at the lowest risk within that life stage.

We evaluated vulnerability at three levels. First, the three attributes that would account for the early life stages encountering the intake screen were assessed. These attributes (reproductive guild, reproductive habitat, and egg characteristics) directly establish the likelihood that a species' eggs or larvae could occur in a portion of the river in which they might encounter the intake structure:

- With regard to reproductive guild, probability of early life stages encountering the intake structure is highest for broadcast spawners (i.e., species that release their eggs and sperm into the water column), intermediate for substrate spawners (i.e., species that deposit their eggs on the bottom substrate), and lowest for nest builders and live bearers.
- With regard to reproductive habitat, probability of early life stages encountering the intake structure is highest for obligate river spawners (i.e., those species that spawn only within riverine environments such as the tidal fresh Mattaponi River), intermediate for facultative river spawners (i.e., those species that spawn in riverine as well as other environments) and lowest for non-riverine spawners (i.e., species that spawn in tributaries, marshes, etc.).
- With regard to egg characteristics, probability of eggs encountering the intake is highest for buoyant eggs, intermediate for demersal and semi-demersal eggs, and lowest for benthic eggs (e.g., eggs deposited in nests). The eggs of some species, including several alosine fishes, exhibit adhesive characteristics that may further mitigate vulnerability to entrainment or impingement.

Table 4-4 presents species-specific data on each of these attributes, the vulnerability scores for encountering the intake, and the sums of the vulnerability scores for encountering the intake for each species. The species with the highest total score (15, striped bass) is an obligate river spawner that broadcasts buoyant eggs, representing the worst case scenario with regard to overall vulnerability of early life stages to entrainment and impingement. Eleven of the 35 species comprising the Mattaponi River fish community were assigned total scores greater than 10 and represent those species most vulnerable to entrainment based on their reproductive ecology.

Table 4-4. Spawning characteristics data for resident and migratory fishes, Mattaponi River, Virginia, with assigned vulnerability to encountering the intake scores. Data are from various sources cited in the text. A blank field means data were not available.

Species	Spawning Temper-ature	Spawning Months	Reproductive Guild	Score	River Spawner	Score	Egg location	Score	Total Score
Alewife	11.0-22.5	MAR-MAY	BROADCAST	5	FACULTATE	3	semi-demersal	3	11
American shad	11.0-20.0	APR-JUN	BROADCAST	5	OBLIGATE	5	semi-demersal/adhesive	3	13
Bay anchovy	15-30	MAY-JUL	BROADCAST	5	NON RIVERINE	1	semi-demersal	3	9
Blueback herring	14-23	MAR-MAY	BROADCAST	5	FACULTATE	3	semi-demersal	3	11
Common carp	15-25	MAY-JUL	BROADCAST	5	FACULTATE	3	Demersal/adhesive	3	11
Gizzard shad	10.0-25.0	APR-JUN	BROADCAST	5	FACULTATE	3	Demersal/adhesive	3	11
Hickory shad	11.0-15.0	APR-JUN	BROADCAST	5	OBLIGATE	5	semi-demersal	3	13
Inland silverside	16-30	MAY-AUG	BROADCAST	5	NON RIVERINE	1	semi-demersal	3	9
Shorthead redhorse	11.0-11.0	APR-MAY	BROADCAST	5	FACULTATE	3	Benthic	1	9
Striped bass	10.0-25.0	APR-JUN	BROADCAST	5	OBLIGATE	5	Buoyant	5	15
Walleye	2.2-15.6	MAR-MAY	BROADCAST	5	FACULTATE	3	Benthic	1	9
White perch	10.0-20.0	APR-JUN	BROADCAST	5	OBLIGATE	5	Demersal/adhesive	3	13
Yellow perch	6.8-12	MAR-APR	BROADCAST	1	OBLIGATE	5	Ribbon	0	11
Atlantic sturgeon	13-20	APR	SUBSTRATE	3	OBLIGATE	5	Demersal/adhesive	3	11
Banded killifish	18-25	APR-AUG	SUBSTRATE	3	FACULTATE	3	benthic/adhesive	1	7
Bowfin	16-19	MAY-JUN	SUBSTRATE	3	FACULTATE	3	Benthic	1	7
Eastern silvery minnow	13-20	APR-MAY	SUBSTRATE	3	FACULTATE	3	Benthic	1	7
Longnose gar	19-21	MAY-JUN	SUBSTRATE	3	OBLIGATE	5	Demersal/adhesive	3	11
Spottail shiner	18.3-19	APR-JUN	SUBSTRATE	3	FACULTATE	3	Benthic	1	7
Tessellated darter	6.5-15.0	MAR-MAY	SUBSTRATE	3	FACULTATE	3	Benthic	1	7
Satinfin shiner	18-30	MAY-JUL	CREVICE	3	FACULTATE	3	Benthic	1	7
Black crappie	15-20	MAY-JUN	NESTER	1	FACULTATE	3	Benthic	1	5
Blue catfish	21-24	MAY-JUN	GUARDER	1	OBLIGATE	5	Benthic	1	7
Bluegill	18-25	MAY-AUG	NESTER	1	FACULTATE	3	Benthic	1	5
Bluespotted sunfish	20.0-20.0	MAY-JUN	NESTER	1	FACULTATE	3	Benthic	1	5
Brown bullhead	21-25	MAY-JUN	GUARDER	1	FACULTATE	3	Benthic	1	5
Channel catfish	21-29	APR-JUN	GUARDER	1	FACULTATE	3	Benthic	1	5
Largemouth bass	15-25	MAY-JUN	NESTER	1	FACULTATE	3	Benthic	1	5
Pumpkinseed	17-30	MAY-AUG	NESTER	1	FACULTATE	3	Benthic	1	5
Redbreast sunfish	20.0-30.0	MAY-JUN	NESTER	1	FACULTATE	3	Benthic	1	5
Redear sunfish	20.0-21.0	MAY-AUG	NESTER	1	FACULTATE	3	Benthic	1	5
Sea lamprey	14-15	APR-JUN	NESTER	1	FACULTATE	3	Benthic	1	5
White catfish	21.0-21.0	MAY-JUN	GUARDER	1	FACULTATE	3	Benthic	1	5
American eel	N/A	N/A	N/A	0	N/A	0	N/A	0	0
Eastern mosquitofish		MAY-JUL	BEARER	1	FACULTATE	3	live-bearer	1	5

The vulnerability index to entrainment and impingement was computed from the three attributes of egg diameter, length of pro-larvae[5], and length of post-larvae.[6] Egg diameter and length of pro-larvae directly establish the potential for the early life stage to pass through the intake screen and be entrained through the 1-mm slot width. Length of post-larvae is related directly to swimming performance and a larva's ability to avoid impingement. Data ranges representing each species and each of these three metrics were derived from various published sources, including Jenkins and Burkhead (1994) and Gowan et al (1999). Vulnerability of these early life stages as a function of their size is based on information presented in Gowan et al (1999). Table 4-5 presents the scores for each of these attributes for the eleven species considered most vulnerable to entrainment and impingement based on their reproductive ecology. American shad, the species of greatest concern in KWR proceedings to date, has a low vulnerability to entrainment and impingement score (due to their relatively large eggs and larvae. However, American shad had a high score for vulnerability to encountering the screens and was considered a species of particular importance in the previous VMRC KWR permit hearing because of its cultural, recreational, and commercial importance. There were also concerns that early life stages of American shad were so fragile that although screens might preclude entrainment, mortality due to impingement and screen contact might still be significant (Mann 2003). We address that issue in detail in Section 5, below.

Table 4-5. Egg and larval characteristics of Mattaponi River fish species considered most vulnerable to entrainment and impingement based on spawning characteristics, with vulnerability scores related to size. A blank field indicates data were not available. Data are from various sources cited in the text.

Species	Egg diameter (mm)	Score	Pro-larvae length (mm)	Score	Post-larvae length (mm)	Score	Total Score
Gizzard shad	0.8-0.8	5	3.5-6.0	5	6.0-12	5	15
White perch	0.8-1.0	5	2.0-4.5	5	4.0-10	5	15
Alewife	1.1-1.2	3	3.9-4.1	5	5.0-16.5	5	13
Blueback herring	0.9-1.2	5	4.4-4.7	3	4.6-18	5	13
Common carp	1.5-1.2	3	4.8-5.1	3	6.5-15	5	11
Striped bass	1.2-4.0	3	2.9-8.0	5	7.0-12	3	11
Yellow perch	1.8-4.0	0	3.7-5.5	5	6.0-11	5	10
Hickory shad	1.1-1.1	3	6.1-6.1	1	6.5-18.0	5	9
Atlantic sturgeon	2.0-2.9	1	11.0-11.0	1		3	5
American shad	2.9-3.4	1	6.5-12.0	1	12.0-30.0	1	3
Longnose gar	3.3-5.0	1	8.0-10.0	1	20.0+	1	3

Six of the eleven species listed in Table 4-5 were identified previously as being the species of greatest concern regarding KWR intake impacts in Mann (2003) and ASA (2003). The species considered most likely to be impacted by the KWR intake in both reports included American

[5] Pro-larvae is a term synonymous with yolk-sac larvae, and refers to the larval fish from time of hatching until full yolk-sac absorption, i.e., through the time of development of a complete, functional digestive system.
[6] Post-larvae is a term synonymous with post-yolk-sac larvae, and refers to the transition stage from development of a complete, functional digestive system to the development of a full complement of fin rays and spines identical to that of an adult.

shad, alewife, blueback herring, striped bass, white perch and yellow perch. The data acquired by Bilkovic (2000) provides a basis for considering an additional vulnerability factor, geographical distribution of spawning. However, as can be seen in the figures, the geographical span and timing of sampling differed among the three years of sampling, and it appears likely that the spatio-temporal scope of the sampling did not encompass the entire spawning area in any of the three years. While limited, the data do provide some insight to how geographical location may influence vulnerability to encountering the intake and vulnerability to entrainment and impingement. Figure 4-2[7] illustrates that nearly all striped bass eggs and larvae taken in three years of sampling were found downstream of the KWR intake location. VIMS, in Mann (2003), concluded that striped bass were at a reduced risk relative to American shad because of their predominant occurrence downstream of the intake. Figures 4-3 and 4-4, presenting a similar plots of American shad and river herring egg and larval distributions, illustrate that eggs of both species are found predominantly upstream of the intake, with larval distributions bracketing the intake area. Figures 4-5 and 4-6 show that white perch eggs and larvae and yellow perch larvae distributions bracket the intake location. These data suggest that all early life stages of striped bass and egg stages of American shad, river herring and yellow perch are likely to have lower probability of encountering the KWR intake than the other life stages of this group of species.

No Mattaponi River-specific data are available on the spatial distribution of early life stages of the other species listed in Table 4-5. Hickory shad appear as vulnerable to both encountering the intake and to entrainment and impingement because of their reproductive biology (Table 4-4) and early life stage characteristics (Table 4-5). However, this species has not been reported in results of the Mattaponi River sampling conducted by VDGIF. Hickory shad tend to spawn in larger tributaries of major rivers (Richkus and DiNardo 1984), but their potential spawning areas within the Mattaponi River watershed are not documented. Similarly, Atlantic sturgeon have not been reported taken in the Mattaponi River in modern times (Jenkins and Burkhead 1993), but a Chesapeake Bay restoration program for Atlantic sturgeon does exist. One factor relevant to sturgeon not accounted for in larval characteristics scored in Table 4-5 is the behavior of the larvae. Recent research on larval shortnose sturgeon behavior indicates that hatchlings are photonegative and vigorously seek cover under any available structure immediately after hatching (Richmond and Kynard 1995). If Atlantic sturgeon larvae behave similarly, this factor would virtually eliminate the potential for the larvae of this species to encounter the KWR intake screen. The common carp (Table 4-5), gizzard shad (Table 4-5) and long-nose gar (Table 4-4) are species with no or very limited commercial and recreational value,

[7] This and suceeding figures presenting egg and larval distributions in the Mattaponi River are plots of Bilkovic (2000) data presented originally in ASA (2003)

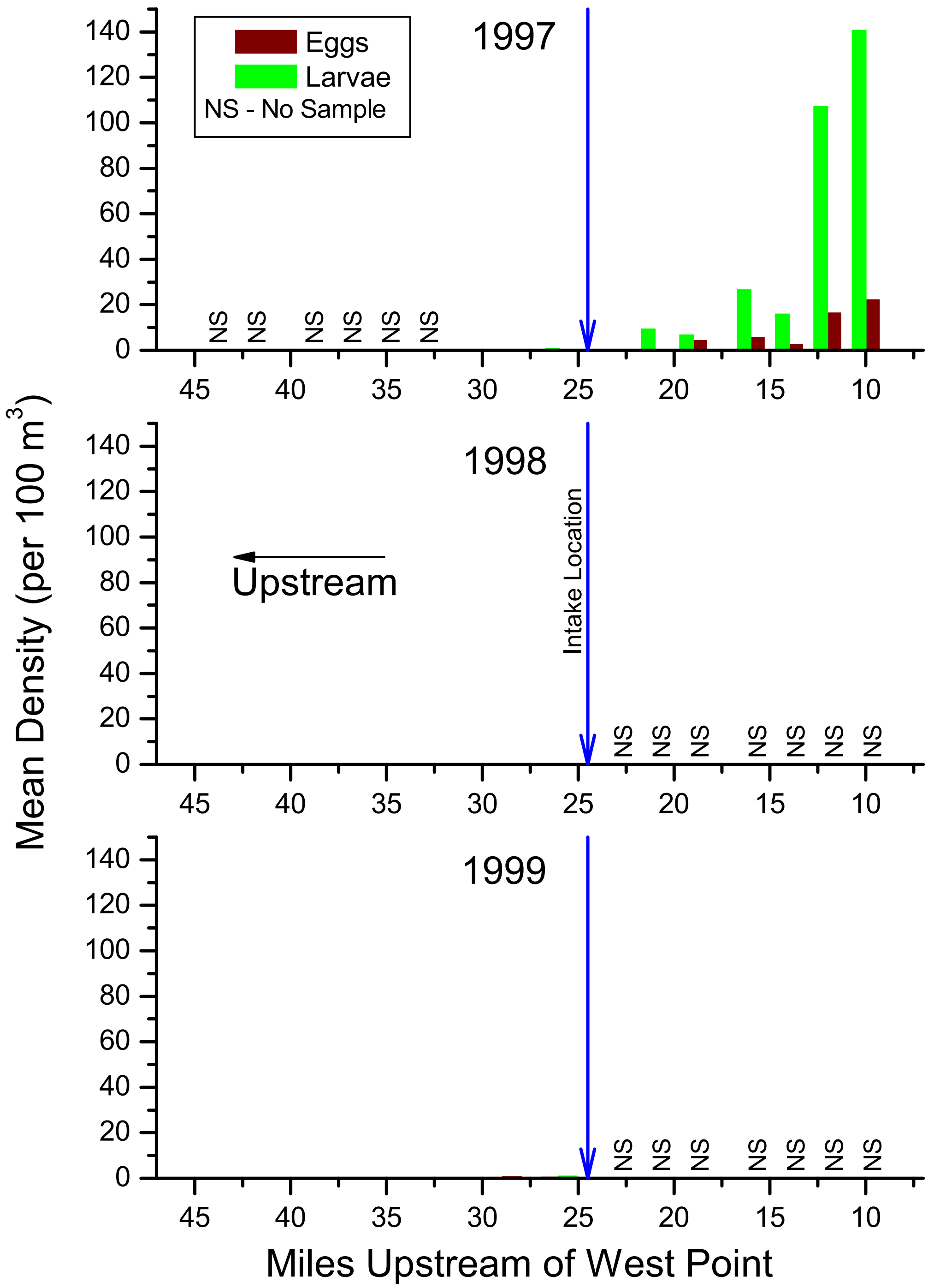

Figure 4-2. Spatial distribution of striped bass eggs and larvae in the tidal Mattaponi River based on sampling conducted by Bilkovic (2000). NS in this and the next four figures indicates no samples taken.

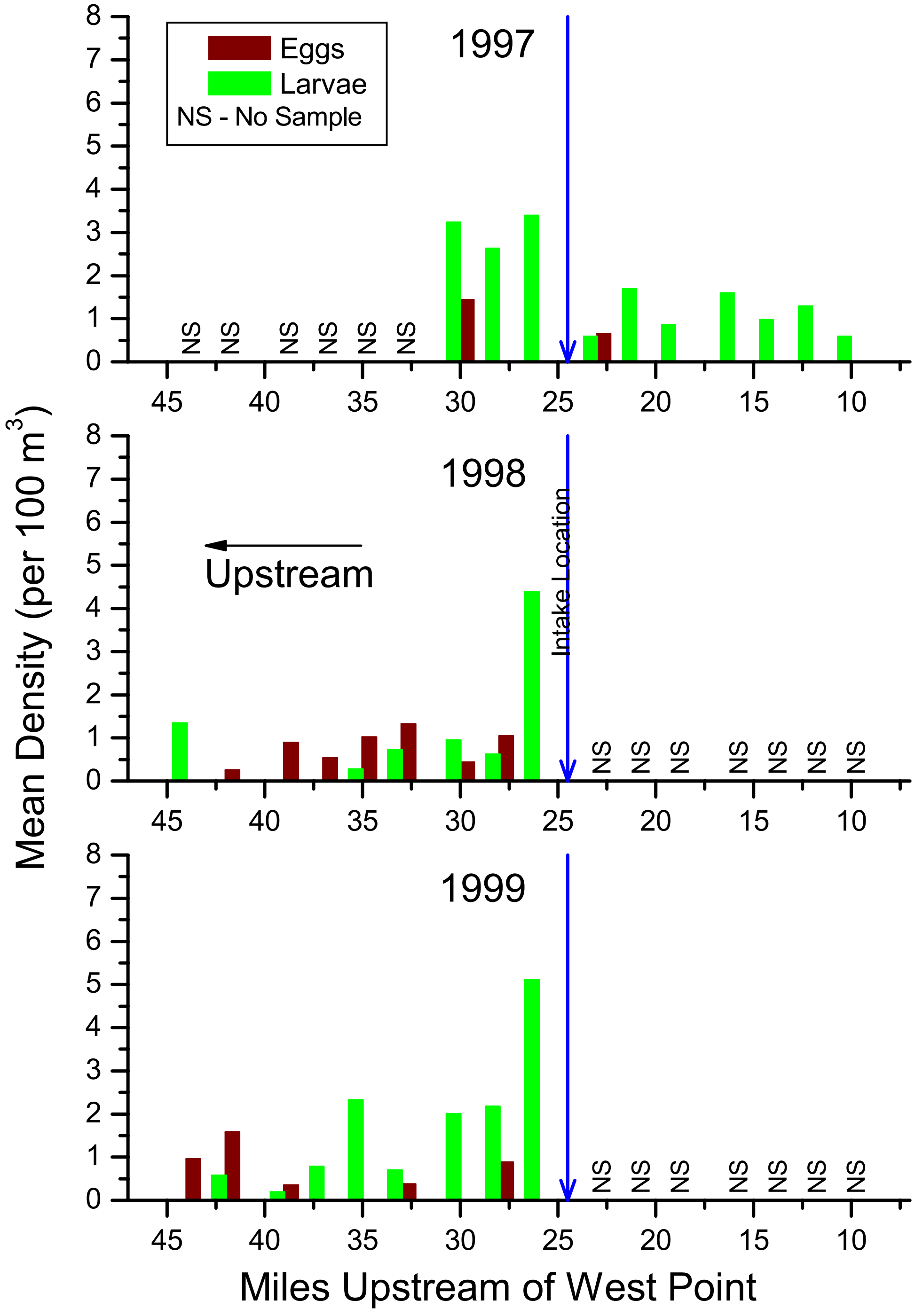

Figure 4-3. Spatial distribution of American shad eggs and larvae in the tidal Mattaponi River based on sampling conducted by Bilkovic (2000).

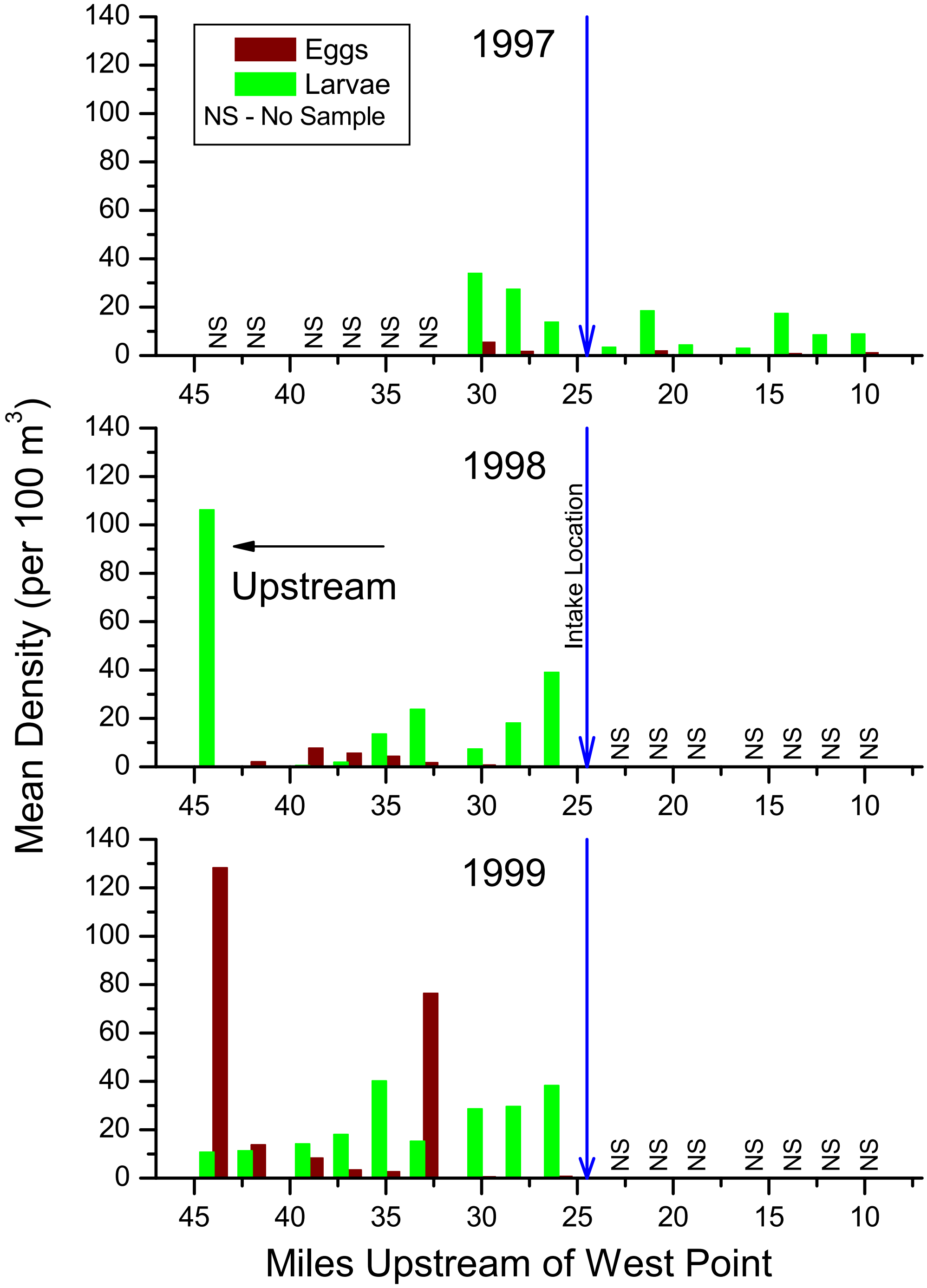

Figure 4-4. Spatial distribution of river herring eggs and larvae in the tidal Mattaponi River based on sampling conducted by Bilkovic (2000).

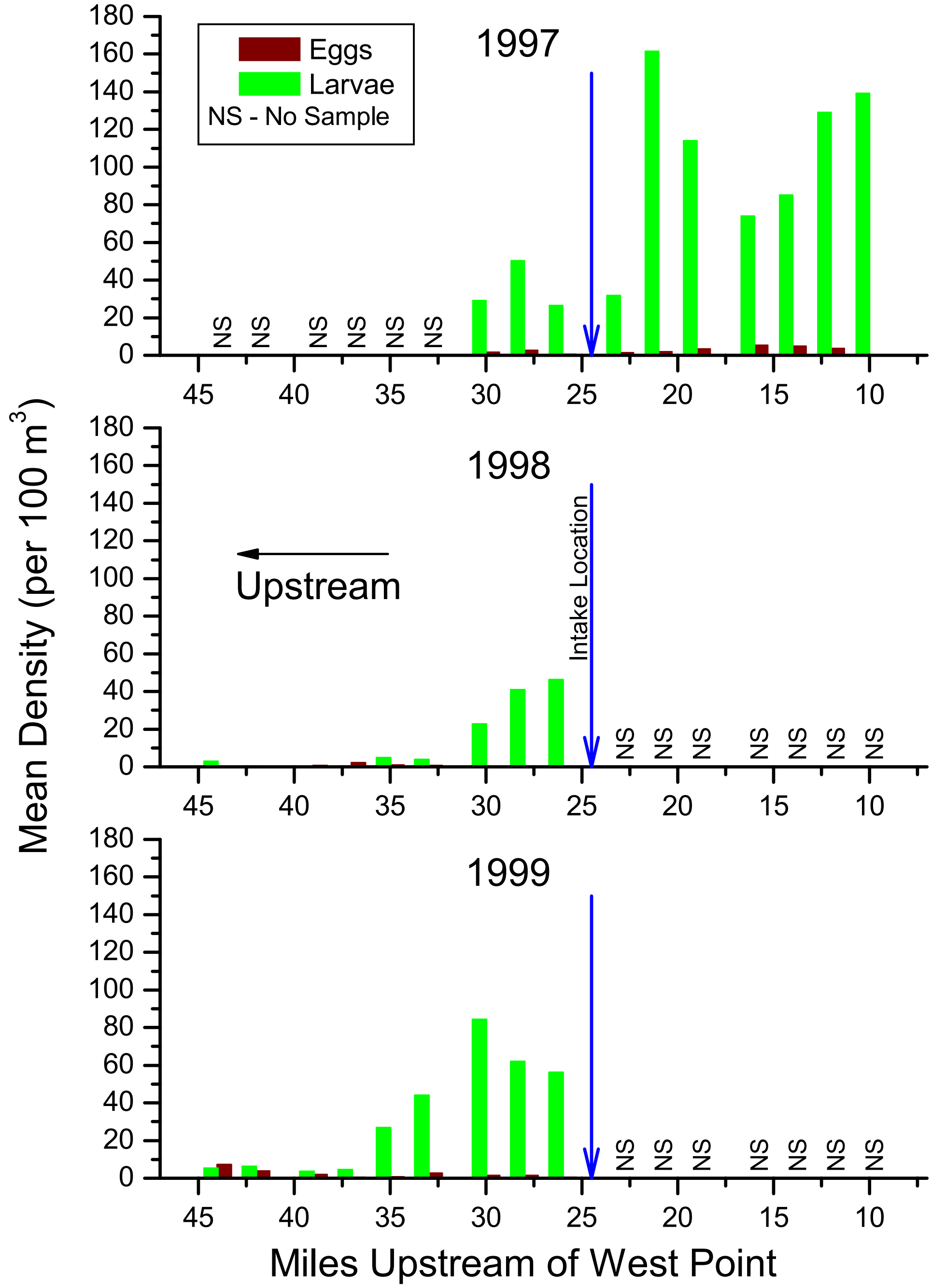

Figure 4-5. Spatial distribution of white perch eggs and larvae in the tidal Mattaponi River based on sampling conducted by Bilkovic (2000).

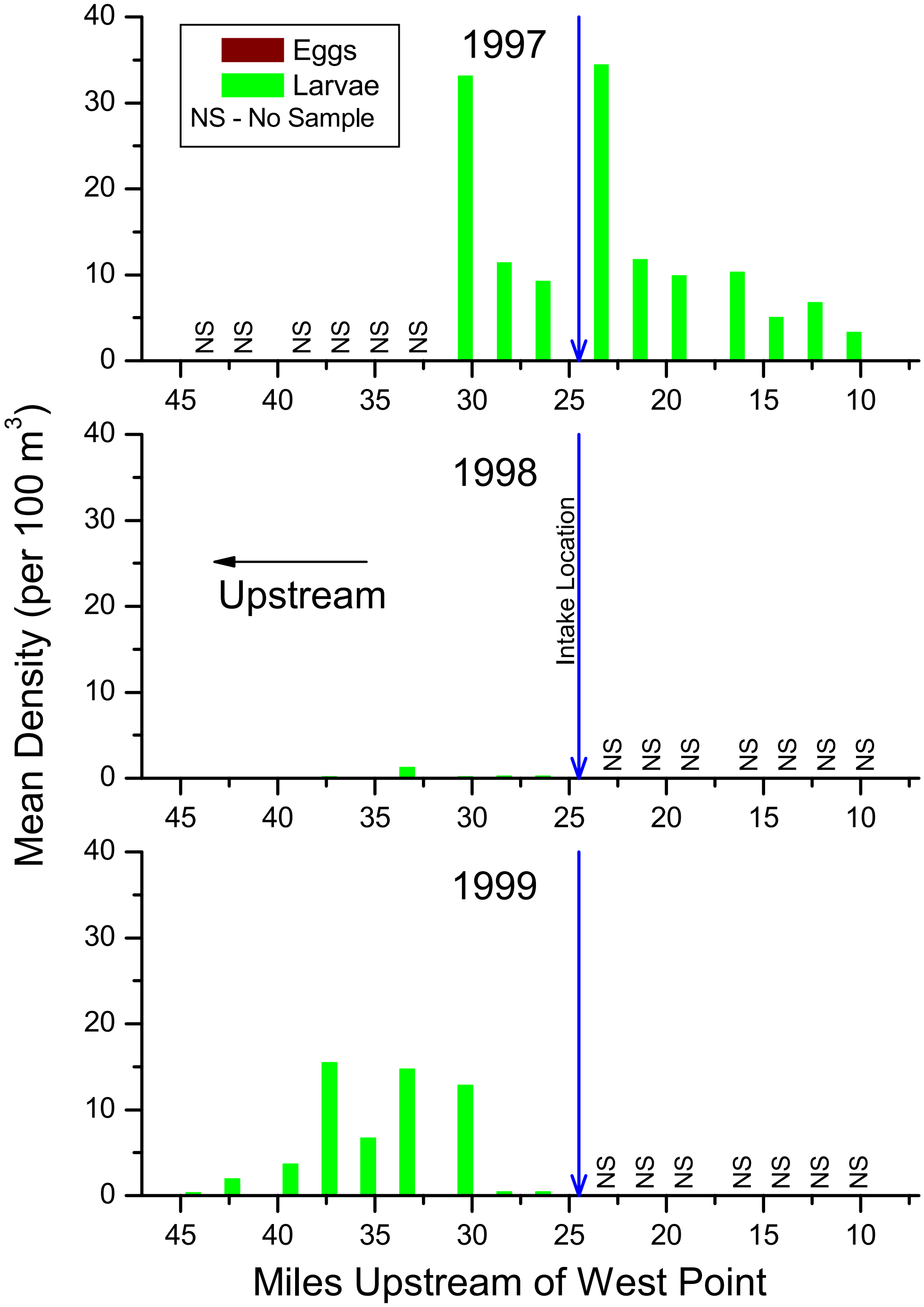

Figure 4-6. Spatial distribution of yellow perch eggs and larvae in the tidal Mattaponi River based on sampling conducted by Bilkovic (2000).

with wide distribution within the York River watershed, and that are considered common and abundant (G. Garman, pers. comm.). Thus, these species were not considered to be of major concern regarding encountering the intake or entrainment impacts and are not addressed further in this report. All of the species listed in Table 4-5 spawn in months that will most likely be nearly completely encompassed by the spring pumping hiatus that will be described in Section 5, below.

4.2.4 Vulnerability to Changes in Salinity Regimes

Changes in freshwater flows within the Mattaponi River are accompanied by changes in the location of the fresh-salt water interface within the river and the steepness of the salinity gradient. All life stages of all species comprising the community that occupy the portions of the river in which that habitat type occurs would be vulnerable to effects of changes of that nature.

4.2.5 Vulnerability to KWR Water Intake Noise

There has been increasing concern in recent years regarding the effect of human-generated (anthropogenic) sounds on aquatic organisms, particularly marine mammals but including fish (Popper 2003). Anthropogenic sounds can range from high intensity (e.g., ship noises, sonar) to low background sounds from machinery. While high intensity sounds may physically injure organisms (e.g., causing loss of hearing), lower intensity noise has the potential for altering normal behavior. Avoidance behavior of fish in response to certain sounds has been actively investigated as a means of directing fish away from potential threats (e.g., from intake screens of power plants) or toward some beneficial location (e.g., entrance to a passage channel around dam turbines). In-river facilities that generate noise could thus inadvertently adversely alter behavior of fish (e.g., interfere with normal migration patterns).

The VIMS staff (Mann 2003) noted that the underwater noise level to be generated by the operation of the KWR intake is unknown, and that little is known about the effects of noise on estuarine fauna. The one-paragraph assessment cited an abstract of a study evaluating the use of hydroacoustic techniques to identify spawning migrations of shad (Gregory 2000). VIMS staff speculated that chronic noise effects on anadromous migratory behavior could affect spawning success. They observed that the Scotland Landing site is fairly narrow, which could increase the potential for noise effects. In the absence of information, VIMS staff judged that adverse effects from noise warranted careful concern.

There is a fairly large scientific literature on aquatic sound and fish, particularly the species of most concern in the Mattaponi River, the American shad and the river herrings. The Panel agreed with VIMS staff that little is known about noise generated by a wedgewire screen intake withdrawing water to a wet-well pumping system, and that this information would be important for evaluating potential KWR effects. The RRWSG contracted for collection of this information at a similar intake located on Lake Gaston, Virginia, operated by the City of Virginia

Beach. The Panel used the sound measurements from the surrogate intake to come to its judgement about the likely impacts of KWR noise (sound) on the key species of concern, especially the American shad, as is discussed in Section 5.

4.2.6 Overview of Vulnerability of Species of Concern

Prior KWR fish impact assessments (Mann 2003 and ASA 2003) were in agreement that the primary species of concern with regard to water intake impacts were American shad, striped bass, alewife, blueback herring, white perch and yellow perch. The intake-encounter and entrainment/impingement vulnerability assessments presented in Section 4.2.3 produced a species list that is consistent with, but somewhat broader than, the prior assessments. A major conclusion from our assessment of potential vulnerability is that juvenile and adult life stages of nearly all species[8] will not be vulnerable to intake impacts (i.e., entrainment, impingement and screen contact) because of the small slot width and low slow velocity of the intake screen. USFWS, in discussions with RRWSG representatives, expressed concerns about potential for the KWR intake to impact Atlantic sturgeon, sea lamprey and American eel. All three of those species were included in the vulnerability assessment presented in Section 4.2.3. American eel and sea lamprey yield vulnerability scores indicating they would not be subject to water withdrawal effect (Table 4-4). Atlantic sturgeon is briefly discussed in Section 4.2.3 and considered to be at low vulnerability to intake effects. Speakers at the VMRC KWR hearing expressed concerns about other species, such as catfish. Again, the vulnerability assessment has taken into account the life history characteristics of such species to indicate that there is low or virtually no probability of water intake impacts to catfish (Table 4-4). However, all life stages of all species that occur in the Mattaponi River in the area of influence of the KWR intake would be vulnerable to the other potential modes of impact described above, including construction, changes in salinity regimes, and noise. In Section 5, we address the each of those potential modes of impact on a generic and not a species specific basis.

[8] Exceptions are very small species, such as bay anchovy and silverside, whose juveniles may be the size of early life stages of larger species.

5.0 KWR INTAKE EFFECTS ON VULNERABLE MATTAPONI FISH SPECIES AND LIFE STAGES

5.1 CONSTRUCTION EFFECTS

5.1.1 Short Term

Short-term effects of construction are those that may occur during preparation for and placement of the intake structures. Dredging, handling of dredged sediments, and any manipulation of bottom sediments can result in increases in turbidity and suspended solids. Fish, particularly in their early life stages when they may not be very mobile, can be exposed to and adversely affected by high turbidity levels (Sherk et al. 1975; Wallen 1951; Breitburg 1988). The procedures to be followed in preparation for and installation of the KWR intake screen header piping, concrete encasement, and riser pipes in the Mattaponi River are described in Section 2.2. Conducting the required dredging using clamshell or backhoe excavator equipment within a sheet pile enclosure minimizes the area of disturbance on the natural river bottom and will preclude dispersion outside of the confined area of turbidity generated by the dredging. Barges will be loaded with the dredged sediments within an area enclosed by a temporary turbidity curtain, to ensure confinement of any turbidity that might result from barge overflow or dredged material being accidentally spilled into the river during barge loading (see Figure 2-4).

Because there are no major municipal or industrial discharges into the Mattaponi River basin and there has been no development at the proposed intake locations, it is highly unlikely that any contaminants reside in sediments to be dredged. Thus, there is no basis for expecting the occurrence of impacts from resuspension of toxics or contaminants. The levels of suspended sediments demonstrated to cause fish mortality tend to be quite high (Burton, 1993). For example, Auld and Shubel (1974) reported that blueback herring and yellow perch larvae could tolerate suspended solids concentrations as high as 1,000 mg/l. Morgan et al (1983) reported the 24-hour suspended sediment LC50 for striped bass larvae to be greater than 20,000 mg/l. Older life stages, such as juveniles and adults, can avoid waters with undesirable levels of turbidity. It is not possible to predict the level of suspended solids that might result from leakage from the sheet pile enclosure or escapement from the turbidity curtain. However, tidal currents would result in rapid dispersion and dilution of any suspended sediments that do escape. It appears highly unlikely, given the proposed procedures and protocols for dredging and construction, that any impacts to fish will be caused by increased turbidity and suspended solids resulting from installation of the KWR intake structures.

During construction, an unobstructed 100 foot wide corridor with a depth of at least 10 feet at MLW will be maintained between the work area and the north shore of the river. Tidal velocities past the construction area in this corridor will be higher than normal as a result of the decrease in river cross-section area. However, the obstructed portion of the river will only extend about 200 feet along the length of the river (see Figure 2.4), so that normal velocities will be attained within a short distance past the construction area, both upstream and downstream. Also, because the currents in the passage corridor are tidal, they reverse direction four times over approximately 26 hours. Thus, elevated unidirectional currents that could adversely affect fish movement will not occur. Juvenile alosines will have to migrate past the construction area during their seaward migration in late summer and early fall. Juveniles of other anadromous species, such as striped bass, will also move downstream into estuarine waters. Most species that do not establish home ranges are likely to exhibit some degree of up and down river movements and are thus also likely to pass the construction area. Because there will be an unobstructed corridor through which movement can take place, no impacts from construction on normal fish movements are expected to occur.

Any impacts that might result from the factors just discussed would be temporary, and would exist for no more than the approximately 6 months of in-river construction in a single year. Single-event impacts of such short duration and so localized in nature, if any were to occur, would not have any significant consequence to sustaining normal populations of any species affected.

5.1.2 Long Term

Long term effects from placement of the KWR intake in the Mattaponi River (separate from those associated with water withdrawal) would result from permanent habitat changes. Two habitat changes occurring would be the creation of large vertical and horizontal physical structures in the water column, and a conversion of some portion of the river substrate from what is most likely silt or silt/clay to stone rip-rap, as was illustrated in Figure 2-3. These types of habitat changes are analogous to what occurs with placement of any hard structure (e.g., pier, bridge, artificial reef) in a water body where none previously existed. Vertical structure and placement of hard substrate in areas of soft substrate result in creation of new epibenthic biomass from organisms that colonize the hard structures (Bohnsack and Sutherland 1985), although such colonization is much lower in freshwaters than in estuarine and marine waters (Bortone and Kimmel 1991). In addition, structure provides cover, which is attractive to many fish species, including forage species, juveniles, and predators that feed on the smaller fish. Creation of structures of this type generally result in concentrating fish in areas where such concentrations did not previously exist. However, there is an unresolved debate among fisheries biologists as to whether such structures merely concentrate fish or actually enhance fish standing stocks (Alevizon and Gorham 1989)

With regard to the KWR water intake structures, epibenthic colonization of the wedge-wire screens themselves will be minimal. The screens are designed and operated to be resistant to fouling so as to permit unobstructed intake flow. However, it is likely that epibenthic organisms will colonize other parts of the structure, as well as the rip-rap placed on the river bottom. It is also likely that the structure itself will attract a variety of fish species that seek structure, such as centrarchids and various species of minnows. Predator species, such as white perch, black crappie and striped bass, may also move into proximity to the structure as a result of increased prey densities. However, relatively high maximum tidal velocities (2.5 to 3.0 fps; see Figure 5-6) at the intake site may limit the diversity and density of fish able to concentrate at the intake. The relatively small surface area of habitat added by the intake structure would have minimal effects on fish distributions in the freshwater tidal portion of the river.

While the net effect of artificial structures on fish populations and structures remains debatable, a preponderance of literature suggests structures in all environments do create localized fish concentrations that make fish more vulnerable to fishing pressure from fishermen (Pickering and Whitemarsh 1997; Grossman, Jones and Seaman 1997). This literature suggests that the effects of the new physical structures comprising the KWR intake structure may result in a concentration of fish in the vicinity of the structure, and as a result could enhance recreational fishing activity and harvest. The small spatial extent of the intake structure would constrain any potential increase in harvest to small levels when viewed on the scale of the tidal freshwater portion of the river.

Some testimony at the VMRC KWR permit hearing raised concerns that the water withdrawal at the intake would cause early life stages of American shad and other species to concentrate in the vicinity of the intake and thus be more vulnerable to predation from larger fish aggregated around the intake structure. The pumping hiatus that will occur during the American shad spawning period under normal intake operation, as described in Section 2.3.1, will eliminate any possibility of hydraulically-induced effects on eggs and yolk-sac larvae of American shad. In drought emergency years, when pumping during the spawning season might occur, the analysis of the behavior of particles in the water flowing past the screens presented in Appendix E clearly demonstrates that it would be physically possible for particles in the water, including eggs and larvae, to become concentrated near the screens only during low-frequency slack tide periods, when sweep velocities are low.

The literature on freshwater artificial structures cited above suggests that they result primarily in redistribution of fish but not an increase in fish populations. Under such circumstances, the location of predatory activity may change, and it is possible that predation rates might increase due to enhanced proximity of predator and prey around the intake. However, the amount of increased predation, when viewed from the perspective of the tidal freshwater portion of the Mattaponi River, is unlikely to be significant.

Another long term effect of placement of the intake structures is a small decrease in the cross-sectional area of the river channel. The presence of the intake structures (e.g., screens and riser pipes) results in a decrease in cross-sectional area of the river at West Point of 1.1 percent (Basco 1996). This would, in turn, result in a 1.1 percent increase in average tidal velocity at the intake location. This small incremental decrease in river cross section would not result in a measurable change in the tidal hydrology of the Mattaponi River and would have no effect on the water surface elevations that could affect aquatic habitat availability to fish.

5.2 OPERATIONAL EFFECTS – IMPINGEMENT AND ENTRAINMENT

5.2.1 Background

The summary of prior assessments of potential fish impacts of the KWR intake (Appendix B) and testimony at the VMRC KWR permit hearing illustrate a number of points of disagreement among KWR stakeholders with regard to entrainment and impingement impacts to vulnerable early life stages. The ASA assessment conducted for the RRWSG (see Appendix B, Sect. 8) assumed that the KWR wedgewire screens provided increasing levels of protection from entrainment to early life stages of American shad and the other at-risk species as they increased in size. The VIMS assessment conducted for VMRC (see Appendix B, Sect. 7), while acknowledging that early life stages of American shad may be excluded from entrainment by the screens, suggested that these life stages are so fragile that they are likely to suffer intake mortality, regardless of whether or not they pass through, are impinged or simply make contact. For this reason, they used an assumption of zero exclusion efficiency of the intake screens in developing their estimates of losses of American shad early life stages. The two assessments also differed with regard to the consequence to adult populations from any losses of early life stages.

In the absence of studies that could resolve the points of disagreement and in the interest of moving their project forward, the RRWSG offered during the VMRC hearing to modify their proposed project to include a pumping hiatus of 60 days during the American shad spawning season. Cessation of pumping would eliminate impingement and entrainment as well as contact with screens induced by water withdrawal, and thus offer nearly total protection to the American shad early life stages. While indicating general agreement with the concept of a pumping hiatus providing a means of avoiding any impacts, VIMS presented data at the VMRC hearing illustrating that the hatch dates of juvenile shad suggested that significant proportions of individual year classes of American shad may originate from eggs spawned during a small portion of the total spawning period. If that small portion of the total spawn were to occur outside the 60-day pumping hiatus, the organisms comprising that portion would still be vulnerable to potential intake impacts, thus in their view still posing a potential risk to the American shad population.

The RRWSG, in convening the KWR Fisheries Panel, instructed the Panel to develop a means of establishing a pumping hiatus that would, with a high degree of reliability, encompass the period during which vulnerable early life stages of American shad would be present in the vicinity of the KWR intake. Such a hiatus was anticipated to also provide a high level of protection to early life stages of the other species deemed vulnerable. Implementation of such a hiatus would make moot any uncertainties regarding the level of protection afforded by wedgewire screens, the proportion of the early life stages subject to impact, and the significance of losses of early life stages to the adult populations in years of normal operation when a hiatus would be implemented.

As will be discussed further below, small fractions of the total standing stock of early life stages of all vulnerable species may still be present within the area of influence of the intake outside the established hiatus in years of normal operation, and a hiatus will not be implemented in what are likely to be infrequent drought emergency years. In these instances, protection of the vulnerable life stages will be afforded by the location, design and mode of operation of the KWR intake. Screen protection effectiveness was thus another important topic for assessment by the Panel.

In order to provide the Panel with comprehensive background information on the fish protection effectiveness of screens of the type proposed for KWR, the RRWSG requested that Panel member Stephen Amaral, with support from other Alden Research Laboratory (Alden) staff, conduct a thorough review of literature and studies available and summarize findings regarding the effectiveness of wedgewire screens for protection of early life stages of fish. Alden was also asked to search for any studies that might relate specifically to the effects of intake screens on American shad early life stages. The Panel had available the comprehensive review of literature on screen protection effectiveness presented in the Virginia Department of Game and Inland Fisheries (VDGIF) report, "Design Criteria for Fish Screens in Virginia: Recommendations Based on a Review of the Literature" (Gowan et al, 1999). However, the Alden Laboratory review represented a significant update to that report, since it took into account studies conducted since 1999, studies in the grey literature that may not be widely available, and the results of two of their own major laboratory studies of wedgewire screen effectiveness completed in 2003. As part of their effort, Alden was also requested to evaluate and characterize hydraulic phenomena that influence the probability of water-borne particles to encounter a screen of the type to be employed for the KWR within a tidal environment, and also studies that might provide insight to levels of mortality that might be experienced by organisms making contact with the intake screen. Drafts of the Alden report, included here as Appendix E, were made available to the Panel for review, and Alden's findings were taken into account in the Panel's deliberations and conclusions.

The remainder of this section discusses the various factors, including the pumping hiatus, that the Panel believes contribute to a high degree of protection of vulnerable early life stages. Details of the process followed in developing the proposed pumping hiatus are also summarized here.

5.2.2 Concept of "Layers of Protection"

As was discussed in Sections 4.2.2 and 4.2.3, only species whose vulnerable early life stages might occur within the area of influence of the intake will be subject to potential entrainment and impingement impacts from the intake. Low slot velocities and small slot widths of the intake screen provide protection from entrainment and impingement. The geographical and bathymetric location of the KWR intake in the Mattaponi River relative to the life history characteristics and spawning habitat preferences of fish species, previously discussed in section 4.2.3, eliminate the potential for intake impacts to most life stages of most species. As the Panel evaluated the various factors that could play a role in potential impact to the early life stages of vulnerable species, the Panel developed a concept of "layers of protection." The "layers" are the various design and operational attributes of the KWR intake that each contribute in different, but cumulative ways, to the avoidance of impacts and redundant protection of the vulnerable life stages. Table 5-1 describes the factors that we considered to be protection layers and how they inter-relate. Each of these factors is addressed in detail in the remaining parts of this section.

Table 5-1. Overview of KWR intake attributes that contribute to layers of protection for Mattaponi River fish populations from intake contact, impingement and entrainment

Attribute	Categories of Fish and Life Stages Protected	Mode of Protection	Magnitude of Protection
Pumping Hiatus	Early life stages of broadcast spawners that are found in the main stem of the river during the hiatus	Avoidance of potential for impact	Nearly complete in years of normal operation
Minimum Instream Flows	Non- or minimally-motile early life stages of broadcast spawners that can be found in the main stem of the river	Constrains withdrawals to levels below maximum design capacity, with magnitude of constraint dependent on magnitude of river flow	Safe yield modeling projected drought emergency withdrawals are limited in most years to well below maximum withdrawal rates
Hydraulic Zone of Influence (HZI)	Non- or minimally-motile early life stages of broadcast spawners that can be found in the main stem of the river	Probability of experiencing intake effects is zero for organisms outside the HZI, but motile life stages may migrate through the HZI	Varies with channel velocity, withdrawal rate and reversing (e.g., tidal) flows.
Tidal Sweep Velocities	Motile as well as non- or minimally-motile early life stages of broadcast spawners that can be found in the main stem of the river	Removes vulnerable organisms from proximity to the intake screen, and thus reduces potential for screen contact, impingement and entrainment	High level of protection during about 85 percent of a normal tidal cycle in the Mattaponi River
1-mm Slot Width	Organisms too large or too inflexible to pass through a 1-mm slot	Eliminates entrainment (but not impingement); most important when sweep velocities are low	Nearly complete
Low Through-Slot Intake Velocity	All species and motile life stages larger than about 10 mm (about ½ in), with swimming speeds greater than slot velocity	Allows for motile organisms to avoid screen contact, impingement and entrainment; allows impinged organisms to escape from the screen; most important when sweep velocities are low	Nearly complete

5.2.3 Pumping Hiatus

5.2.3.1 Identifying Potential Triggers for Initiation and Termination of a Pumping Hiatus

The concept of a pumping hiatus is that water withdrawal from the Mattaponi River would be terminated during the period when American shad early life stages vulnerable to intake effects were present. Such a hiatus would have to be defined by some type of trigger that would signal plant operators when to cease pumping and when pumping could be reinitiated. The Panel's development of potential triggers began with designation of the life stages that were to be afforded protection. The major fish impact concern expressed during the VMRC hearing was for American shad, and potential for impact to this species was specified in the VMRC denial of a KWR Subaqueous Lands Use Permit. Thus, the instruction of the RRWSG to the Panel was to establish triggers that would assure virtually complete avoidance of any potential intake impacts to American shad early life stages. Avoidance of impacts to other important vulnerable species was desired but not designated as a specific objective of the hiatus.

As was noted in Section 5.1, above, VIMS (Mann 2003) considered American shad eggs to be fragile and subject to mortality from screen contact, thus constituting a vulnerable life stage. VIMS also considered "larval stages" of American shad to be subject to mortality from screen contact, but did not distinguish between yolk-sac and post-yolk-sac. ASA (2003) presented a projection of American shad larval growth based on literature data and projected wedgewire screen effectiveness as a function of larval size. That analysis suggests that wedgewire screens provide 100 percent exclusion for larvae 10 mm in size or larger. A size of about 10 mm is also supported as being a reasonable cut-off criterion for vulnerability (longer larvae are not vulnerable) by Gowan et al (1999) and by the Alden Laboratory literature review (see Appendix E). Such a size corresponds to the post-yolk-sac life stage of American shad, which has a length range of 9 to 27 mm. The discussions of fish swimming speeds in Section 5.2.3, below, and in Appendix E confirm that fish of such length are capable of swimming speeds sufficient to avoid contact with or impingement on the KWR screens. Thus, the two life stages of American shad designated for protection by the pumping hiatus were eggs and yolk-sac larvae.

The Panel next considered variables that would be most feasible for use as triggers. The primary criteria for selection were that they be measurable and strongly predictive of the presence of the vulnerable early life stages. Clearly, the presence or absence of the target life stages themselves would be the most definitive trigger possible. However, "real-time" monitoring for eggs and larvae to serve as an efficient trigger would present numerous logistical challenges: sampling would have to be nearly continuous; sampling would have to be intense to assure detection when densities are low; and samples would have to be processed immediately on a real-time basis. For these reasons, the Panel investigated environmental variables that might serve as reliable surrogates for the presence or absence of the target life stages. Shad spawning behavior is influenced by numerous environmental variables, in particular time of year, water temperature and river flow (e.g., Bilkovic 2000; Limburg et al, 2003). Temperature is widely recognized as the primary factor controlling spawning (e.g., Funderburk et al, 1991; Carlander

1969). The Panel determined that water temperature offered the greatest potential as a trigger that would be measurable and predictive of early life stage presence.

To be used as a trigger, the specific temperatures that would be indicative of the presence or absence of eggs and yolk-sac larvae of American shad in the Mattaponi River would have to be established. The only American shad early life history data available from the Mattaponi River was that from Bilkovic (2000). While 3 years of data were available, it appears that the full spatio-temporal occurrence of the early life stages may not have been covered in all three years. In addition, three years of data would be insufficient for statistically rigorous assessment of potential temperature trigger values. Other researchers in the Chesapeake Bay region were consulted about availability of data from long term studies of American shad early life stages (see Appendix C), and none were identified. However, the Panel was aware of long term, rigorously designed ichthyoplankton surveys of the portion of the Hudson River that encompassed the American shad spawning grounds (the Hudson River fisheries program is described in Appendix C). The Panel determined that this 30-year data set, with accompanying water temperature data, provided a sound basis for investigation of the feasibility of establishing temperature triggers that would achieve the protection levels desired.

Appendix C presents the details of data used in our analyses and the analytical approach taken in investigating potential temperature trigger values. Four steps were followed in assessing the feasibility and merits of temperature triggers:

Step 1. Compare temperature patterns in the Hudson River estuary with temperature patterns in the Mattaponi River to determine if the Hudson could serve as a reasonable surrogate with regard to rate of change in water temperature over the American shad spawning period.

Step 2. Determine the relationship between water temperature and the abundance of American shad eggs and yolk-sac larvae in the Hudson, and use that relationship to identify temperature triggers that might be appropriate to achieve the desired levels of protection of standing crops.

Step 3. Evaluate the timing (calendar dates) and duration (number of days) of a pumping hiatus associated with selected temperature triggers based on long-term temperature records from the Hudson River estuary. Such information was essential for use by the RRWSG to ensure that the water supply project could still be viable with the recommended pumping hiatus.

Step 4. Estimate the level of biological protection of early life stages afforded by a pumping hiatus based on various combinations of temperature triggers for four of the vulnerable species in the Mattaponi River that were also taken in the Hudson River sampling program (American shad, river herring, striped bass, and white perch)

As discussed in Appendix C, there were limited but sufficient multi-year continuous spring temperature data available from tidal fresh portions Chesapeake Bay tributaries, particularly for the Pamunkey River, and substantial temperature “grab samples” from the Mattaponi River for use in Step 1. Figure 5-1, from Appendix C, plots Mattaponi River temperature grab sample data versus long-term Hudson River water temperatures for similar Julian dates. These data and other analyses presented in Appendix C illustrate that Hudson River temperature trends (i.e., the rate of warming) over the spring spawning period was very similar to those observed in the Mattaponi River, but offset by about one month. These data and analyses suggested that if American shad spawning was triggered by the same temperature levels in both the Hudson and Mattaponi Rivers, the duration of spawning would be similar, although offset in time by about a month.

As an outcome of Step 2, Figure 5-2, from Appendix C, shows the cumulative percentage standing stock of American shad eggs and yolk-sac larvae present in the Hudson River spawning area over the range of temperatures recorded over the 30 years sampled. This exploratory analysis suggested that temperatures of 10 °C and 22 °C might reliably predict the occurrence of most of the American shad eggs and yolk-sac larvae in the Hudson River in most years.

Analyses performed as part of Step 3 showed that the length of time between the occurrence of 10 °C and 22 °C temperatures in the Hudson River ranged from 44 days to 83 days over the 30-year sampling program. The time period was most commonly 50 to 70 days, and averaged 61 days (see Figure 7 in Appendix C). The RRWSG determined that durations of that average magnitude during non-drought emergency years would not compromise the water supply objectives of the reservoir project, confirming the feasibility of a spawning season pumping hiatus. Their explanation for the fact that a pumping hiatus that varied in duration so substantially from year to year could be accommodated was that water stored in the KWR, as well as the other parts of the Newport News Waterworks water system, provided the means of meeting demand until river flows were sufficient to allow increased withdrawals in accordance with their VDEQ permit requirements.

Attachment 2 of Appendix C presents the levels of protection to the target species provided by different potential temperature triggers. Table 5-2 (Table 1 of Appendix C) shows the outcome of Step 4, the level of protection provided to American shad eggs and yolk-sac larvae by application of the 10 °C and 22 °C triggers, as well as the protection provided by the 10 °C and 22 °C triggers for the early life stages of three of the other Mattaponi River vulnerable

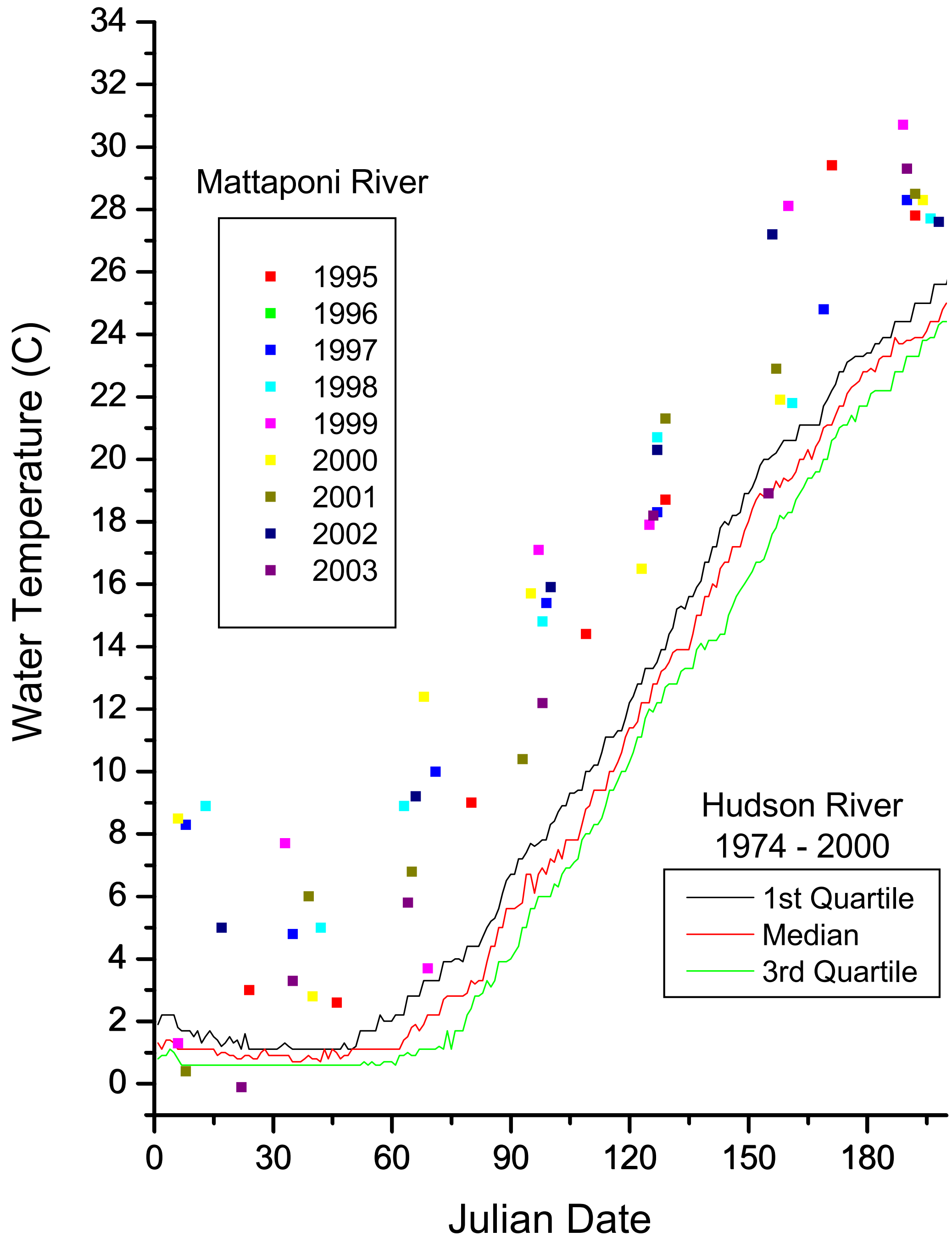

Figure 5-1. Comparison of spring water temperature measurements taken in the Mattaponi River using grab samples just upstream from Scotland Landing to overall patterns in the Hudson River estuary near Poughkeepsie, NY

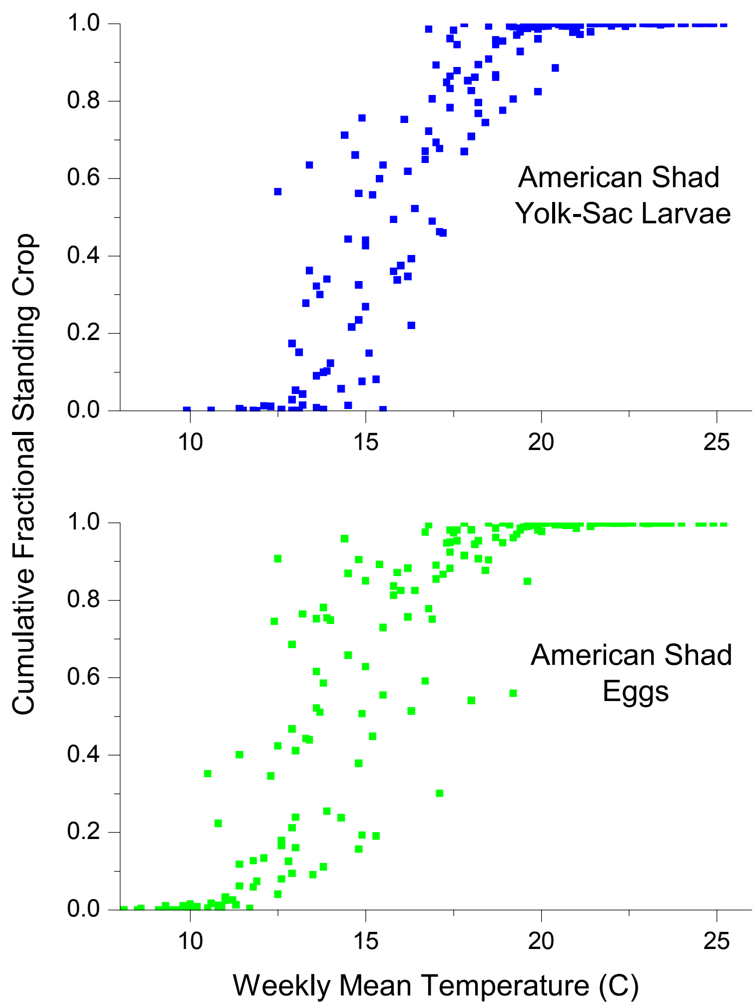

Figure 5-2. Relationship between the cumulative fractional standing crop of American shad eggs and yolk-sac larvae and weekly mean water temperatures in the Hudson River estuary, 1974 – 2000. Cumulative fractional standing crop is computed from weekly standing crop estimates by adding each week's standing crop to standing crops from previous weeks and dividing by the sum over all weekly standing crops.

species that were also collected in the Hudson River program. These data illustrate that, for those years in which the entire spawning season was covered[9], the 10 °C and 22 °C triggers would provide 100 percent protection of the standing crop of American shad yolk-sac larvae and no less than 97 percent protection to the standing crop of American shad eggs in any year (100 percent protection in 9 of 12 years). Minimum protection levels with the 10 °C and 22 °C triggers applied to the 18 years of data were 98 percent for river herring eggs and yolk sac larvae, 99 percent for striped bass eggs and yolk sac larvae, and 99 percent for white perch eggs and yolk sac larvae. Protection levels provided to post-yolk-sac stages tend to be lower because this life stage is reached later in the overall spawning period. Most post-yolk-sac larvae that are relatively large, such as those of American shad (9-27 mm) would not be vulnerable to entrainment or impingement. However, the post-yolk-sac larvae of species that have smaller larvae, such as river herring and white perch, would be somewhat more vulnerable to entrainment and impingement. The 10 °C and 22 °C triggers still provide relatively high levels of protection to post-yolk-sac-larvae of river herring and white perch. For both river herring and white perch, post-yolk-sac protection levels were greater than 86 percent in 16 of 18 years, and minimum protection levels in any single year were 73 percent and 75 percent, respectively, for those two species.

5.2.3.2 Implementation of a Mattaponi River-Specific Pumping Hiatus

Having established that water temperature could be used as a trigger for a pumping hiatus to achieve desired levels of protection, the Panel next considered what measures would be required to establish reliable Mattaponi River-specific temperature triggers. Site-specific temperature and biological data are required to establish such triggers. The Panel recommended to RRWSG that collection of such data be initiated as soon as possible, with the objective of acquiring a multi-year, long term data base on temperature and presence and absence of early life stages of American shad and other vulnerable species that could be used to develop appropriate temperature triggers prior to initiation of any water withdrawal for KWR. RRWSG informed the Panel that it would be a minimum of 8 years after the project was fully permitted before any water withdrawal could occur, with the likelihood of that time period being several years longer. Based on this time schedule, the Panel designed a preoperational monitoring program that is

[9] As explained in Appendix C, years in which sampling started after the 10 °C temperature was reached were not included in this assessment because it could not be assured that the entire spawning period had been covered in the sampling programs in those years.

Table 5-2. Estimates of the percent of the annual standing crop of each life stage that occurs within the period defined by 10 °C and 22 °C in the Hudson River estuary, 1974 – 2000.

Year[a]	American shad[b]		River herring			Striped bass			White perch		
	Egg	**YSL**	**Egg**	**YSL**	**PYSL**	**Egg**	**YSL**	**PYSL**	**Egg**	**YSL**	**PYSL**
1974	100.00	100.00	100.00	100.00	98.81	100.00	100.00	99.29	100.00	100.00	98.61
1975	100.00	100.00	99.67	100.00	95.94	100.00	99.99	98.89	100.00	99.99	97.85
1976	97.12	100.00	98.20	98.57	74.95	100.00	99.94	88.73	99.85	99.90	80.61
1977	97.35	100.00	99.91	99.99	97.33	99.99	99.99	99.67	99.94	100.00	98.76
1978	99.12	100.00	99.99	100.00	98.63	100.00	99.99	96.08	100.00	100.00	99.53
1979	97.34	100.00	99.91	100.00	99.39	100.00	100.00	99.61	100.00	100.00	99.21
1980	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1989	98.89	100.00	99.47	100.00	98.50	100.00	100.00	99.45	99.98	100.00	98.59
1990	100.00	100.00	100.00	100.00	96.21	100.00	99.99	93.30	99.95	99.99	93.98
1992	100.00	100.00	99.98	99.50	96.22	100.00	100.00	99.56	100.00	100.00	98.20
1993	100.00	100.00	100.00	100.00	88.76	99.97	99.98	97.23	99.91	99.99	94.15
1994	99.92	100.00	99.99	99.99	87.28	99.98	99.91	95.09	99.56	99.96	91.15
1995	98.16	100.00	98.67	99.95	88.68	99.97	99.79	87.55	98.63	99.90	88.28
1996	100.00	100.00	100.00	99.91	81.56	99.95	99.98	95.51	99.98	99.95	86.23
1997	98.85	100.00	98.19	99.99	82.08	99.99	99.80	91.50	99.95	99.92	72.90
1998	100.00	100.00	100.00	100.00	99.99	100.00	100.00	99.82	100.00	100.00	99.60
1999	100.00	100.00	100.00	99.85	86.02	100.00	100.00	98.62	99.98	100.00	96.28
2000	99.89	100.00	99.91	100.00	99.84	100.00	100.00	99.99	100.00	100.00	99.86

[a] Years from 1981 through 1988 and 1991 not included since sampling was not initiated until after water temperatures had already reached 10 °C.

[b] American shad post yolk-sac larvae (PYSL) not considered susceptible to entrainment at the KWR intake as a result of large size and strong swimming abilities.

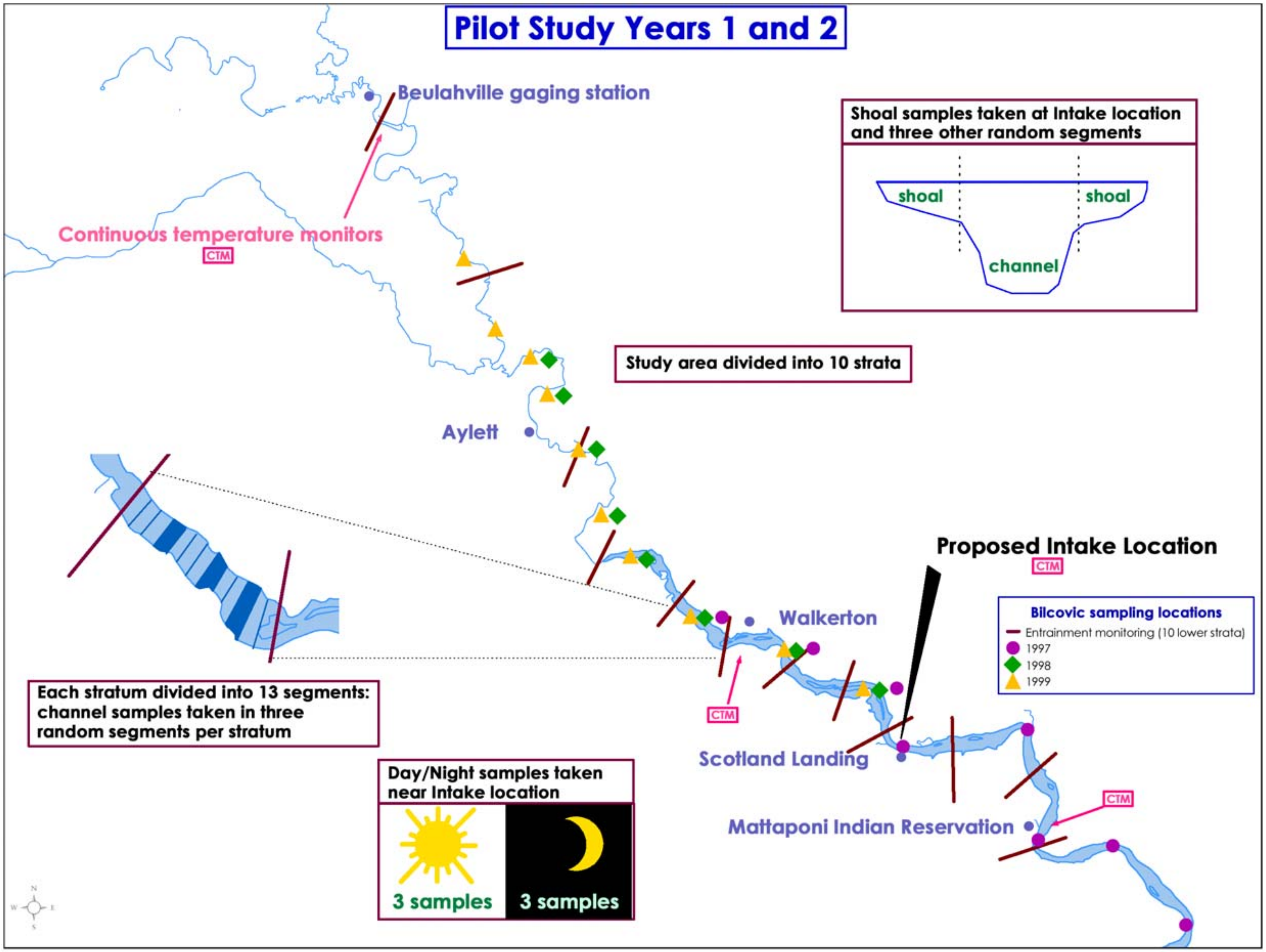

Figure 5-3. Diagramatic depiction of the KWR preoperational monitoring program (see Appendix D for details)

described in detail in Appendix D. This program, visually depicted in Figure 5-3 which is drawn from Appendix D, includes the following elements:

- Installation of four continuous temperature monitors that bracket the American shad spawning area within the Mattaponi River
- Stratified random sampling over the entire spawning period and over a 60 km reach of the Mattaponi River that encompasses the entire potential spawning area of American shad
- Limited shoal (where applicable) and night sampling to ensure the representativeness of channel, daylight samples
- Continuation of annual sampling for a minimum of 8 years and for all years prior to initiation of water withdrawal
- Concurrent implementation of a hatch-date study on junveile American shad that will provide data useful for verification of the level of protection afforded to American shad eggs and yolk-sac larvae by the temperature triggers

The data analysis methodology for establishment of the Mattaponi River-specific temperature triggers would be similar to that used in exploratory analysis of the Hudson River data, and the suggested approach for doing so is described in Appendix D. However, an important step in the application of the temperature triggers to the Mattaponi is the specification of the level of protection to be achieved by the temperature triggers. The RRWSG requested that the Panel develop triggers that could ensure virtually complete (e.g., 100 percent) protection of the vulnerable early life stages of American shad. However, the Panel recognizes the many uncertainties associated with collection of biological and environmental data in the field and the natural and sampling variability that are likely to be encountered in long term studies of this type. High variability in ichthyoplankton density estimates are to be expected, particularly at the beginning and end of the spawning period when densities of organisms are very low. For example, the protocols employed in analysis of the Hudson data and to be used on Mattaponi data include estimation of standing stock within strata by extrapolating mean densities from three samples per strata to the entire strata volume. Thus, as an extreme example, one egg taken in one sample could result in a standing stock estimate of thousands for a single strata that would be incorporated into trigger development. Such factors make accurate assurance of total protection nearly impossible.

Because the magnitude of variability and uncertainty will not be known until a number of years of data are available from the preoperational monitoring program, a priori statistical confidence limits on magnitude of protection cannot be established. Taking these factors into account, the Panel decided that feasible criteria for levels of protection, based on results of analyses of Hudson River data, would be a minimum of 97 percent absolute protection of American shad eggs and yolk-sac larvae standing crops in 7 of 8 years of study, and no less than 95 percent absolute protection in any single year. This latter lower protection percentage is in recognition of potential for unusual, infrequent events impacting study results. To further reduce potential for uncertainty, the Panel has recommended that RRWSG commit to implementation of a pumping hiatus over a temperature range of at least 12 ^{o}C, corresponding to the range between the temperatures of 10 ^{o}C and 22 ^{o}C, even if results from the preoperational monitoring program suggest a smaller temperature range would achieve the protection objectives. Committing to a hiatus duration in terms of temperature range rather than specific temperatures allows for a Mattaponi-specific hiatus that may be initiated at a somewhat higher or lower temperature than the 10 ^{o}C if monitoring results indicate that would be appropriate. Because of the RRWSG commitment, results of preoperational monitoring could potentially result only in an expansion of the hiatus temperature range beyond the 12 ^{o}C range.

In addition, the Panel is also recommending concurrent implementation of a hatch date study, that will document the "date of birth" of juvenile shad produced in each year. These data would provide a means of verifying the efficacy of the Mattaponi River-specific hiatus temperature triggers derived from the preoperational surveys. However, because of their importance for verification, hatch date analyses must be subject to rigorous quality control and quality assurance measures, as was noted in Appendix D. Aiken (2000) notes that hatch date frequency distributions can be misleading because they are a combined reflection of abundance, natural mortality, and residence time of individual cohorts in the sampling area. Their validity is certainly dependent on the juveniles aged being quantitatively representative of the entire yearclass. Wilhite et al (2003) discuss many of the factors that can affect the representative sampling of juvenile American shad and the validity of juvenile indices of abundance as representing future adult yearclass size. These concerns regarding hatch dates are the basis for Panel's decision to base the trigger development protocol on a rigorously designed ichthyoplankton sampling program. Detailed analyses of preoperational data, particularly from the more intensive pilot study years, will provide a basis for resolving any discrepancies that may arise between the results of the preoperational ichthyoplankton monitoring program and the hatch date analyses.

5.2.3.3 Minimum Instream Flows

Minimum instream flows (MIFs), considered the second protection layer, act to constrain the volume of water that can be withdrawn to below maximum design withdrawal levels. In the two instances when pumping may occur when vulnerable life stages are present (within the spring but outside the hiatus period in normal years, and in the spring of drought emergency years), the protection of the MIFs will be of greatest significance. While the time of termination of the hiatus will be established based on water temperatures and data acquired in the long-term preoperational monitoring program, based on existing information, it is likely to be at the end of May or beginning of June. As was shown in Figure 2-5 and is discussed in Appendix F, beginning in summer months, the MIFs restrict the volume of water that can be withdrawn from the river to a substantial degree. In drought emergency years, which are expected to be infrequent, safe yield modeling results presented to the Panel and shown in Table 2-3 illustrate that MIFs restricted withdrawals to less than maximum in five of the 6 years modeled, with the level of restriction ranging from 34 to 86 percent. In the one year in which maximum withdrawal of 75 mgd was predicted, river flows were exceptionally high and the 75 mgd was about 12 percent of flow. As is evident from these figures, the potential level of protection provided by the MIFs will be highly variable, but will be highest under low flow conditions. Coincidentally, American shad larval survival rates have been shown to be inversely proportional to river flow and water temperature (Crecco and Savoy, 1987). Thus, the MIFs may provide the greatest degree of protection under circumstances most favorable to early life stage survival.

5.2.3.4 Intake Hydraulic Zone of Influence (HZI)

The hydraulic zone of influence (HZI) is defined by the USEPA as that portion of the source water body hydraulically affected by the intake structure's withdrawal of water (see Appendix E). Projections of the fractional loss of American shad and other species early life stages due to KWR water withdrawal (ASA 2003; Mann 2003) assumed that all organisms within a defined portion of the water body from which water is withdrawn have equal probability of entrainment, impingement or screen contact. VIMS, in Mann (2003), considered that portion to be defined by one tidal excursion distance upstream and downstream of the intake. The ASA report (ASA 2003) considered that portion to be the volume of the nursery area as estimated using the geographic range of the larval stages of each species. The Alden report (Appendix E) indicates that the hydraulic characteristics of an intake designed and operated in the manner proposed for KWR do not support the assumption of equal probability of removal. Recent studies demonstrate that only organisms within the hydraulic zone of influence (HZI) have any probability of encountering or passing through the intake screen.

Figure 5-4 (provided by Alden) shows the distribution of velocities measured in a vertical plane, aligned with the centerline of a cylindrical tee screen installed in Alden's fish testing facility as part of the EPRI (2003) study. These data were used to validate the results of a three-dimensional simulation of flow into the intake structure and the results of the computation were used to visualize the movement of flow into the intake as shown in Figure 5-5 (provided by Alden).

Alden's flow field evaluations show that under most tidal conditions, the water entering the intake approaches from a narrow region directly upstream of the structure. In the case of the proposed Mattaponi intake, where sweep velocities would exceed through-slot velocities on the order of 90 percent or more of the time, Alden's experimental results suggest that the intake would withdraw water primarily from the center of the river cross section and that organisms present near surface and bottom and in the shoals would not be vulnerable to entrainment. The measured velocities and simulated streamlines in the Alden study indicate passive particles farther than about one foot from the screen surface would be carried downstream, even in the situation when slot velocity (0.78 ft/sec) was faster than the sweep velocity (0.5 ft/sec).

The size of the HZI and the how it affects probability of entrainment was examined in an extensive Alden study of a Connecticut power plant, described in detail in Appendix E. The facility had a shoreline intake located in a tidal freshwater portion of the river where the tidal excursion distance was similar in magnitude to that at proposed intake location at Scotland Landing on the Mattaponi River. That study found large differences in the probability of encountering the intake for organisms present in different sectors of the river cross-section upstream of the plant's intake. Probabilities ranged from zero in the sectors farthest from the intake to 26 percent in the sectors nearest (see Figure 14 in Appendix E). Such percentages are not directly applicable to the KWR intake because of the differences in the source water body, and the design and location of the intake. However, the results do illustrate the significance of the HZI concept with respect to the probability of a particle encountering an intake structure.

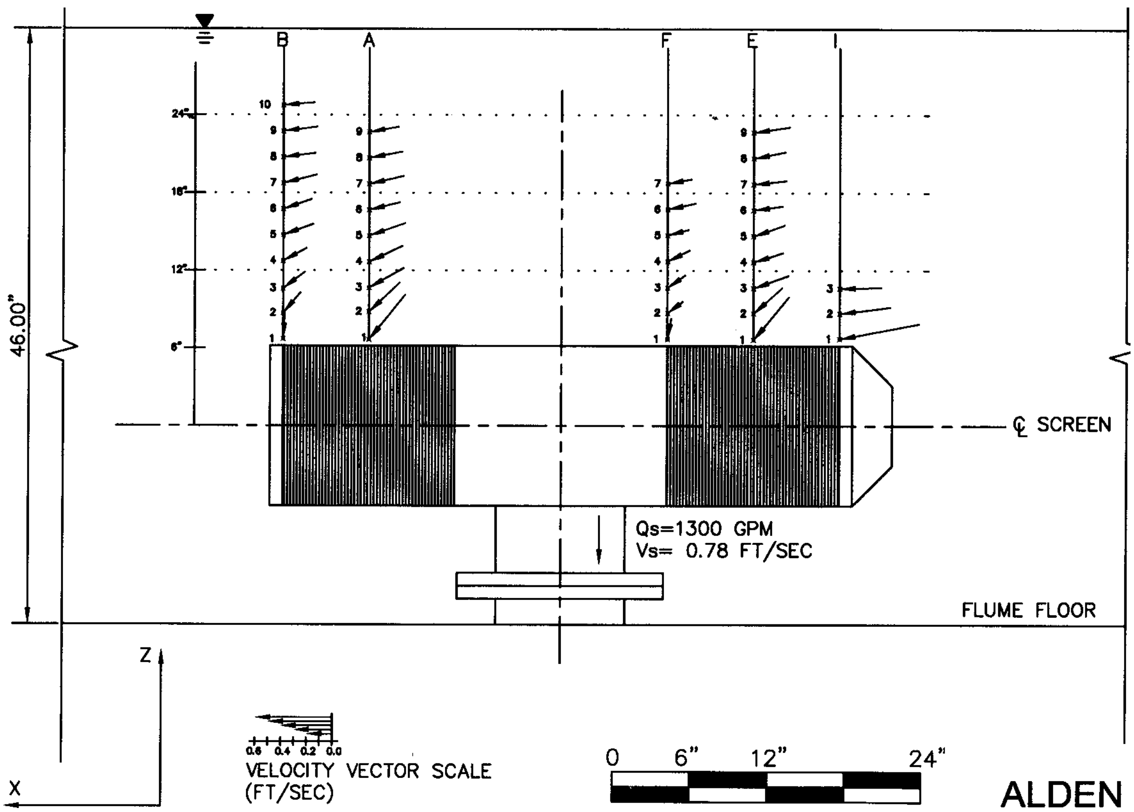

Figure 5-4. Wedgewire screen flow direction and magnitude measured with an acoustic Doppler velocimeter (EPRI 2003). Flume velocity was set at 0.5 ft/s and through-slot velocity at 0.78 ft/s.

Alden made "back-of-the-envelope" calculations to estimate the probability that organisms passing the KWR intake would encounter the intake screen, as a function of their location in the water column, under a range of operating and tidal conditions (see Figures 15, 16 and 17 in Appendix E). The results presented in those figures are intended to illustrate the role that withdrawal rates, sweep velocities and location in the water column play in affecting the probability of particles occurring in proximity to the intake screen. They do not represent true estimates of entrainment risk, since they depict probabilities only during a single pass of the water by the screen, and assume that particles are evenly distributed throughout the river cross section. However, the results do indicate that it is likely that a substantial portion of the organisms passing the KWR intake screen on any single tidal cycle would not be exposed to intake screen contact and effects. The dimensions of the HZI would be smallest during maximum tidal velocities and largest during zero or low tidal flow periods. Bilkovic (2000) concluded, based on fast sinking rates and lack of later developmental stages in her collections, that American shad eggs reach the bottom soon after spawning and may remain near where spawning occurs. Most eggs reported in her study were found upstream of Scotland Landing, suggesting that this life stage of American shad may be unlikely to occur within the KWR HZI at the intake site under most conditions. Larval behavior described by Bilkovic (2000), consisting of repeatedly swimming to the surface and the passively sinking, would result in larvae being more evenly distributed throughout the water column than eggs, and thus more likely to occur within the HZI.

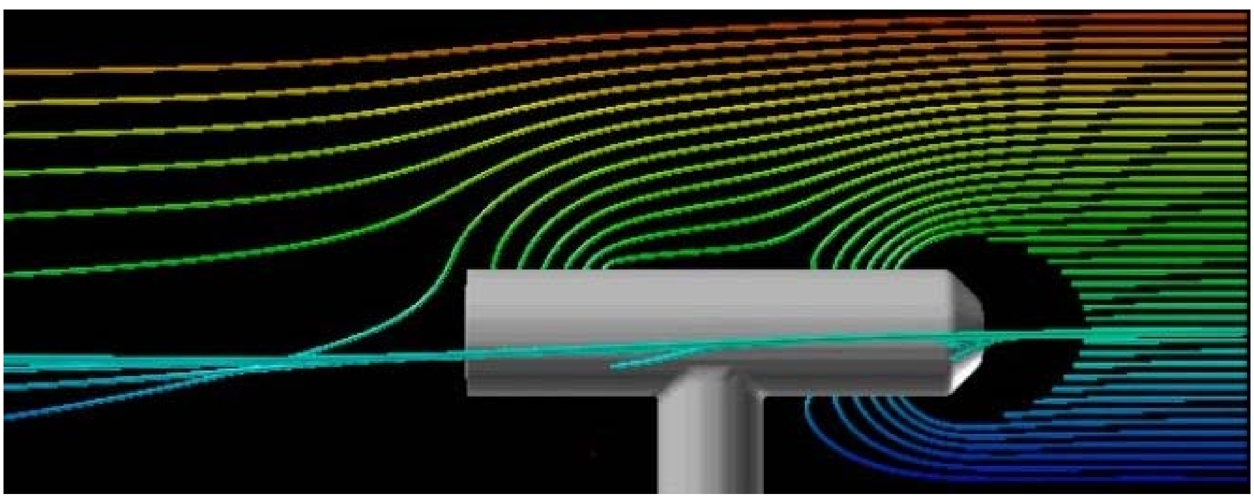

Figure 5-5. Flow streamlines for a cylindrical wedgewire screen generated from a numerical model (EPRI 2003).

While the degree of protection afforded by the HZI at the KWR intake cannot be reliably quantified, some inferences can be drawn from the experimental studies and analyses described in Appendix E. Those vulnerable organisms present in the water column near bottom, near surface and in the shoal areas will have very low to zero probability of encountering the intake screen during the majority of the tidal cycle, when tidal velocities are substantially higher than through-slot velocities. Highest probabilities of screen encounters would occur around slack tide periods and at highest withdrawal rates. Prior discussions (Section 2.3.1 and 2.3.2) indicate that maximum withdrawal rates are likely to occur infrequently, even in drought emergency years when spring withdrawals will be permitted. Taken together, all these factors suggest that the HZI does provide some level of protection to vulnerable life stages, with that protection level varies with stage of the tidal cycle and the spatial distribution of organisms within the water column. All organisms within the spawning area will not be susceptible to intake effects.

5.2.3.5 Screen Slot Width, Through-slot Velocities and Sweep Velocities

The role of screen slot width, through-slot velocities and sweep velocities in providing protection from intake effects on vulnerable organisms are closely interrelated. Organisms present within the HZI have some probability of being drawn toward, contacting or being drawn through the intake screen. Alden identified nine studies of wedgewire screens (see Table 1 in Appendix E) that demonstrate that these screen attributes, alone or in combination, influence the degree of entrainment and impingement of fish eggs and larvae in different ways: (1) small slot sizes physically block passage of organisms into the intake system; (2) low through-slot velocities provide protection to passive or weak swimming organisms from being trapped on the screen face; and (3) ambient currents (i.e., “sweeping” velocity) carry organisms and debris away from screens and thus beyond the influence of the through-slot velocities. The relative importance of any these attributes in maximizing early life stage protection varies with changes in other attributes. For example, the same levels of protection provided by screens with small slot widths, low slot velocities and modest sweep velocities could be achieved by screens with larger slot widths and higher slot velocities, if sweep velocities were higher. Table 5-3 (data extracted from Table 5 in Appendix E) illustrates this relationship for surrogate striped bass eggs; striped bass eggs have no mobility. No entrainment occurs because of the size of the artificial eggs. Impingement of the artificial eggs was higher at the higher slot velocity, and very high when the sweep velocity was lower than the slot velocity. However, no impingement occurred when sweep velocity was twice the slot velocity (the issue of the magnitude of mortality that might be caused by impingement and/or contact with the intake screen is addressed in a later section), and impingement was less than 1 percent when the sweep and slot velocities were equal.

Appendix E presents much more comprehensive data from the nine studies that strongly confirm that wedgewire screens, when deployed as proposed for the KWR and when significant sweep velocities occur, do not act like a passive sieve, straining out particles and organisms present in the water column. Ambient tidal currents that will provide sweep velocities for the KWR intake screens will range, on average, from 0.0 ft/s during slack tides to 2.5-3.0 ft/s at peak tidal flows (Figure 5-6). Average tidal velocities will be twice or greater than the maximum through-slot velocities for about 85 percent of the tidal cycle. However, the tidal cycle presented in Figure 5-6 is the long term average for proposed intake located at Scotland Landing, and day-to-day tidal flows can vary substantially, depending on such factors as magnitude of freshwater inflow and wind-induced movement of water into and out of the York River estuary. While such factors would clearly affect tidal velocities at any given time, the long term average velocities suggest that high sweep velocities will occur at the KWR intake for the majority of the tidal cycle under most circumstances.

Table 5-3. Data extracted from Table 5 of Appendix E, illustrating the influence of channel (sweep) velocity on impingement rates of surrogate striped bass eggs. Slot size is that proposed for the KWR intake screen, but the lowest slot velocity is twice the maximum KWR slot velocity. Velocity has been converted to English units for the benefit of the reader. "Imp" is impingement and "Ent" is entrainment.

Slot Size (mm)	Slot Velocity (ft/sec)	Channel Velocity (ft/s)	Mean Percent of Test Organisms that were Impinged or Entrained (SD in parentheses) Surrogate Striped Bass Eggs Imp	Ent
1.0	0.5	0.25	91.0 (14.7)	0.0(0.0)
		0.5	0.3 (0.6)	0.0(0.0)
		1.0	0.0 (0.0)	0.0(0.0)
	1.0	0.25	98.7 (1.2)	0.0(0.0)
		0.5	88.7 (3.5)	0.0(0.0)
		1.0	0.0 (0.0)	0.0(0.0)

In Appendix E, Alden used data from tests with the 1-mm slot screen reported in EPRI (2003) to develop a multiple regression model in which the dependent variable was the mean proportion of fish excluded by the screen and the independent variables were channel to slot velocity ratio and fish length. Use of a model to predict performance of the KWR intake screen was necessary because design maximum slot velocity for the KWR screen was half the lowest slot velocity tested by Alden, and sweep velocities in the tests were lower than what will occur at the KWR intake 80 to 90 percent of the tidal cycle. The multiple regression model was used to predict exclusion efficiencies based on fish size and channel velocity for slot velocities of 0.10 and 0.25 ft/s (i.e., most common operational velocity and maximum for the KWR screens).

As seen in Figure 5-7 (Figure 9 in Appendix E) at a slot velocity of 0.10 ft/s or less, complete exclusion is predicted to occur for larvae 12 mm or greater when channel velocities reach 0.40 ft/s, which occurs over most of the tidal cycle (Figure 5-6). Complete exclusion of larvae greater than 5 mm is predicted to occur at 0.10 ft/s when channel velocities are 0.7 ft/s or greater, which occurs approximately 80 percent of a tidal cycle. The Panel acknowledges that the regression equation results in an extrapolation to KWR design velocities that extends beyond the bounds of the data used in developing the regression. This factor contributes to an unknown degree of uncertainty in the quantitative predictions. However, the test results themselves and the regression predictions strongly support a conclusion that the combination of low slot velocity and high sweep velocity at the KWR will offer a high degree of protection to organisms exposed to intake effects.

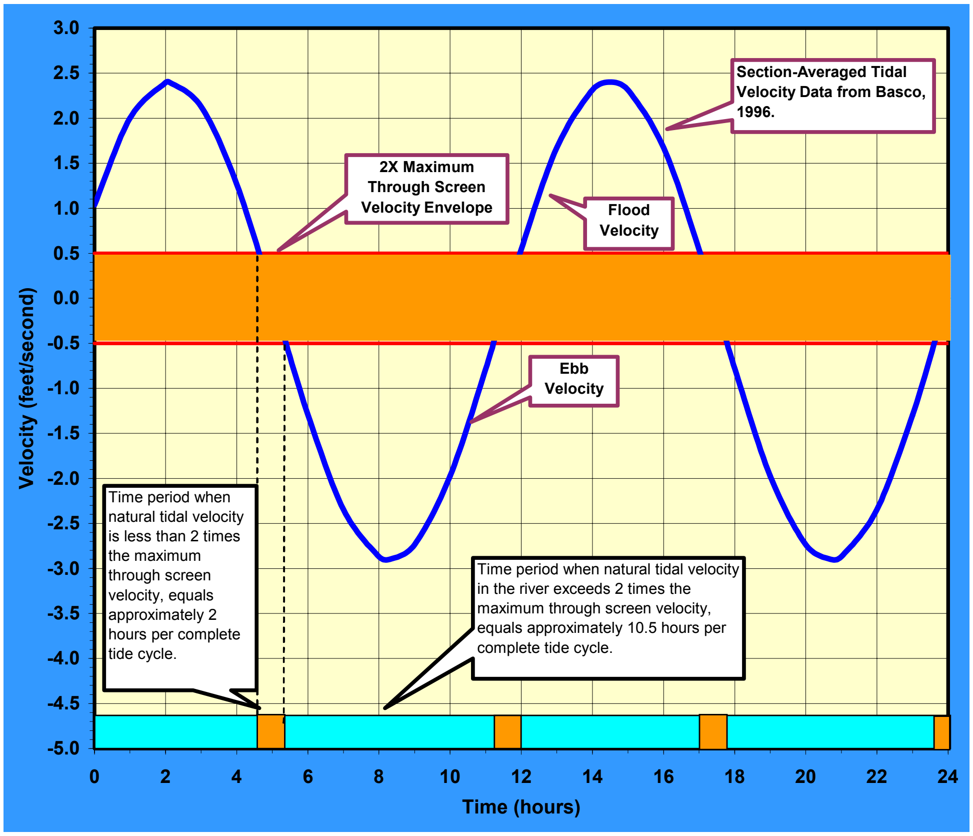

Figure 5-6. Tidal velocities of Scotland Landing (modified from Basco 1996)

The findings of Alden Laboratory studies pertaining to wedgewire screen exclusion from entrainment and impingement of fish eggs result from the hydraulic characteristics of flow fields and the behavior of non-motile particles suspended in those flows. Results with larvae, while being partially a result of hydraulics, are greatly influenced by the motility of the organisms. The fact that fish swimming capability is function of size is the reason that exclusion efficiencies shown in Figure 5-7 increase with fish size under all test conditions. This swimming ability is of particular importance when sweep velocities are low, which in the case of the KWR intake would occur during slack tide periods. At those times, sweep velocities would not be present or sufficient to transport fish away from the screen, and impingement of fish on the screen could occur. Aquatic organisms trapped in such a manner may die of exhaustion, suffocation or other injuries, even if they were later swept away from the screen. However, in the absence of sweeping velocities, approach velocities perpendicular to the screen face will still dissipate rapidly to levels (< 0.1 ft/s) that even small larvae (5-10 mm) should be able to avoid at distances

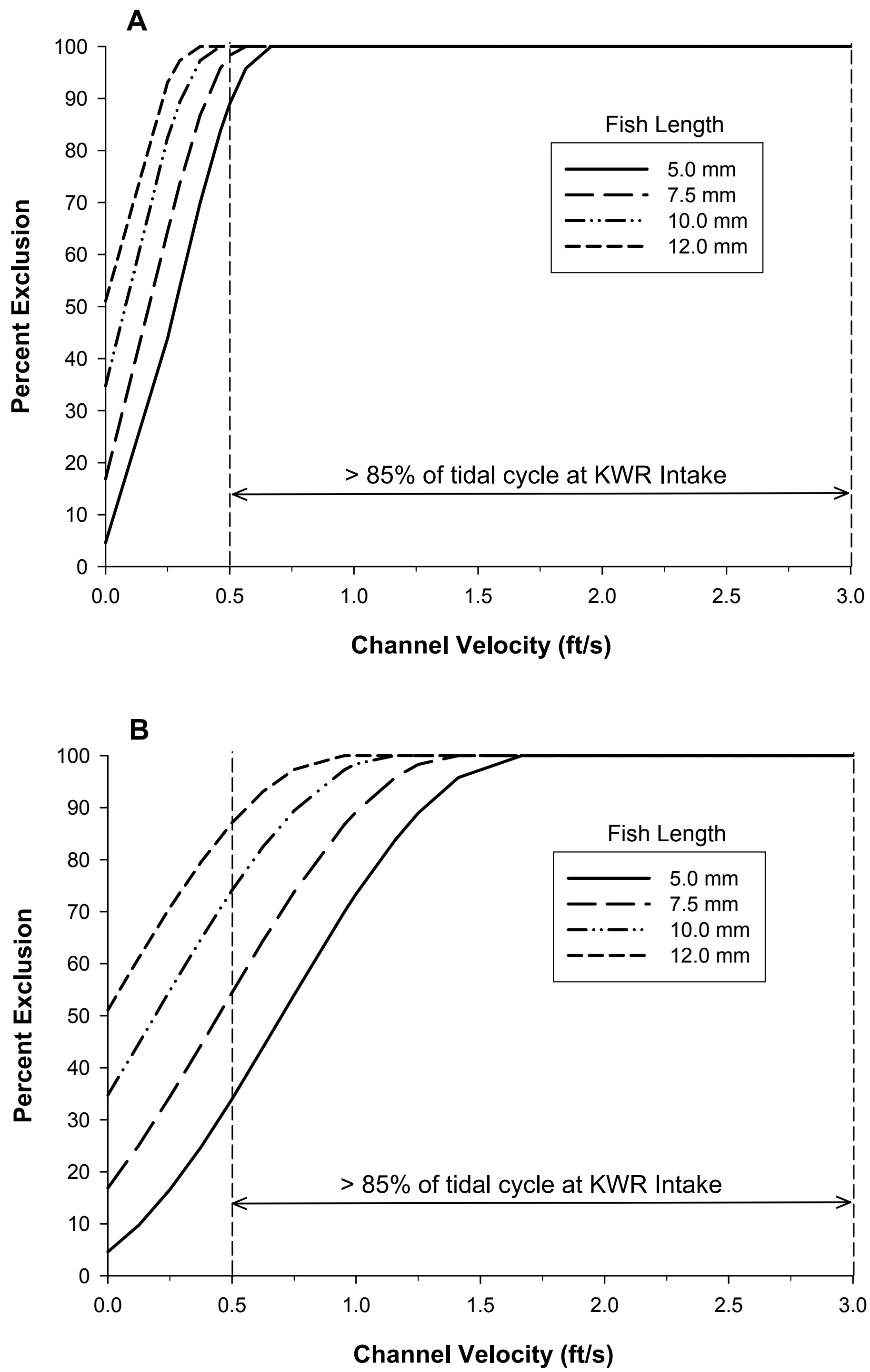

Figure 5-7. Screen exclusions rates by channel velocity for a 1-mm slot screen with through-slot velocities of 0.10 ft/s (A) and 0.25 ft/s (B). Exclusion rates were generated from a multiple regression analysis of entrainment data from EPRI (2003). Independent variables included ratio of channel to slot velocity and fish length. (Figure 9 in Appendix E.)

greater than 1-2 feet from the surface of the screens. Also, at these distances from the screen, semi-buoyant eggs are likely to drop from the water column towards the river bottom during slack tide periods.

Studies described in more detail in Appendix E and summarized here have shown that some larvae small enough to pass through 1 mm screen slots have sufficient swimming ability to avoid entrainment. Hanson et al. (1978) and Hanson (1981) showed that the percentage of striped bass larvae capable of swimming away from an operating screen and avoiding entrainment and impingement in the absence of sweeping flows increased with fish size (i.e., larger fish were stronger swimmers). While the data on swimming speeds of fish larvae are limited, and we could find no specific data on swimming speeds of American shad larvae, the existing data confirm that primarily eggs and yolk-sac larvae, which range in size from about 5 to 10 mm, would be vulnerable to entrainment and impingement by the KWR intake screens, and that vulnerability would increase during slack tides but be much lower during the majority of the tidal cycle when sweep velocities were more than double the maximum through-slot velocity.

5.2.3.6 Potential Impacts to Vulnerable Early Life Stages from Screen Contact

A final issue with regard to potential for intake effects is the fate of eggs and larvae within the HZI that do come into contact with the intake screen. We noted earlier that VIMS was of the opinion that eggs and larvae of American shad were so fragile that they would suffer mortality from screen contact with the KWR, regardless of whether they were impinged. Alden conducted a comprehensive review of screen intake literature to identify any studies that investigated screen contact mortalities with American shad or other fragile species (see Section 4 of Appendix E). While levels of entrainment and impingement at wedgewire screen intakes can be quantified experimentally with relative ease, the indirect effects on remaining organisms are more difficult to ascertain. Differentiating the effects of contact with the structure from the handling effects of collecting specimens for analysis requires a carefully executed experimental design. In Appendix E, Alden notes that there are few studies that directly assess mortality of eggs and larvae that come in contact with wedgewire screens. However, they did identify several studies of impingement-induced mortality at other types of exclusion devices that provide insight into potential effects. The three modes of impact from screen contact are shear, turbulence, and contact abrasion. These modes have not been studied directly as they relate to wedgewire screens, but other exclusion devices have been examined in laboratory tests and those findings are relevant to the issue.

Hanson et al. (1978) quantified potential mortality to striped bass eggs associated with impingement on wedgewire screens. Mortality attributable to impingement ranged in individual trials from 0 percent to 11.9 percent. However, the mean impingement mortality ranged only from 0 percent to 2.0 percent and the overall mean mortality for all developmental stages was 1.4 percent (see Table 6 in Appendix E). Most mortality took place within the first 30 minutes after impingement. Mortality was highest in the earliest stage of development (late-gastrula), which may indicate a higher degree of fragility of that life stage.

An unpublished study by Radle (2001) was conducted to estimate mortality of American shad eggs induced by impingement on the Gunderboom Marine Life Exclusion System (or aquatic filter barrier, AFB). The Gunderboom is a fabric-like material designed to exclude eggs and larvae from entrainment in water intakes. It has very fine mesh and low through-mesh velocities. In experimental jars, 100 live shad eggs were placed on fabric pieces and flow was provided at a velocity of 0.1 ft/sec. The eggs remained impinged for predetermined periods of time, ranging from one to four hours. Only 7 of the 1200 eggs used in the study (including both control and test eggs) had died after 24 hours. Survival rates in all jars were 99 percent or higher.

Laboratory studies were conducted by ESEERCO (1981) to evaluate the mortality of several species of larval fish (including striped bass, winter flounder, and alewife) following impingement on fine-mesh screens. Impingement on 350 or 500 micron mesh screens was evaluated by introducing larvae into a flume upstream of the test screens. Tests were performed at several approach velocities ranging from 0.5 to 2.0 ft/sec and for impingement durations ranging from two minutes to sixteen minutes. This study suggested that mortality rates were highest at the highest approach velocities (i.e., analogous to through-slot velocities and not sweep velocities), and impingement mortalities were consistently high. However, control mortalities were also high, which confirms the difficulties in obtaining reliable mortality data from studies of this nature.

These and other studies summarized in Appendix E provide some indication that contact with, and temporary impingement on, fine mesh screens do not cause total mortality of the affected organisms, and, for some species and life stages (e.g., striped bass eggs), induced mortality may be low. Thus, eggs and larvae that may make contact with the screen, be temporarily impinged during slack tide periods at the KWR intake, and then dislodged when sweep velocities increase, may have some degree of survival. However, the existing literature is not sufficient to quantify the level of survival of American shad larvae that might be expected. In discussing American shad egg and larvae fragility, hatchery procedures used in culturing American shad for restoration programs were described to Panel members. Fertilized shad eggs are placed in hatching jars in which they are kept suspended through use of aerators. Visual observation of these hatchery jars suggest that during their entire incubation period, eggs and newly hatched larvae are exposed to agitation and contact with jar walls and other structures present in the jars, with no significant induced mortality (W. Dey, personal communication). Whether the magnitude and nature of physical contact with structure in such instances is comparable to what may occur at the KWR intake screen is not known. However, these observations do illustrate that American shad eggs and larvae are capable of surviving some degree of physical encounters with objects.

5.2.3.7 Cumulative Protection Benefits of Layers of Protection

Figure 5-8 depicts graphically the KWR intake attributes contributing to protection of vulnerable early life stages. The pumping hiatus to be implemented in accordance with the recommendations of the Panel, the first protection layer, will provide absolute protection to nearly all but at minimum 97 percent of the egg and yolk-sac-larval stage standing crops of American shad in years of normal operation. It will also provide a high degree of protection to vulnerable life stages of other species. Because the protocol for calculating level of protection afforded by the hiatus is based on standing crops of early life stages calculated for the entire spawning region in the Mattponi River, some of the vulnerable life stages present when pumping is reinitiated could be in areas not subject to water withdrawal effects (e.g., more than one tidal excursion downstream). The organisms that may be in locations susceptible to withdrawal effects are subject to the remaining protection layers. Those same protection layers apply to vulnerable life stages of all species that may be present in the infrequent drought emergency years when spring water withdrawals might occur.

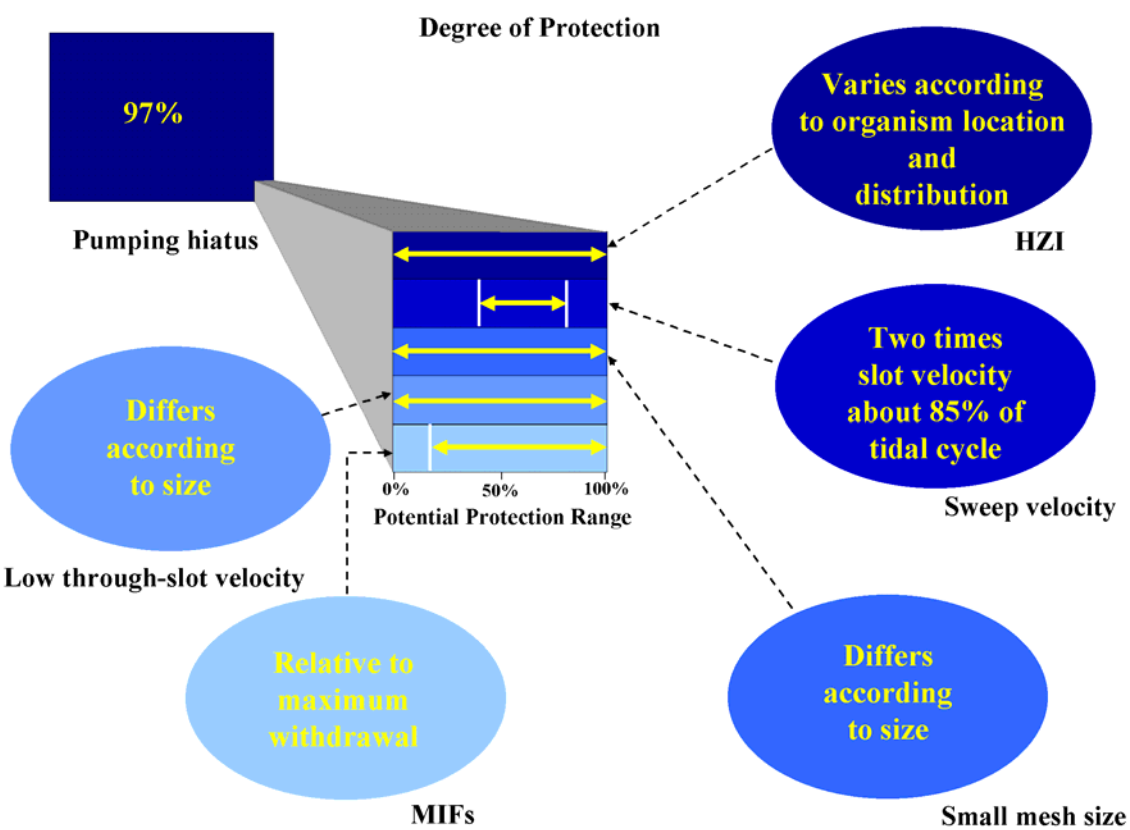

Figure 5-8. Diagrammatic representation of KWR intake layers of protection.

Minimum instream flows (MIFs) offer protection relative to the potential maximum withdrawal rate. As discussed above, safe yield modeling results show that water withdrawals in the spring months in years of drought emergency could regularly be constrained to much less than maximum. The level of protection provided by MIFs is highest when flows are lowest. But even at high flows, when maximum withdrawal might be permitted, the withdrawals would represent a relatively small proportion of the total water available, and thus potential for impacts even under those circumstances are limited.

The Panel concludes that the studies and findings discussed here, and in greater detail in Appendix E, are sufficient to reject the conservative assumption that wedgewire screens of the design proposed for KWR provide no protection to vulnerable early life stages. The available literature confirms that each attribute of wedgewire screens (hydraulic zone of influence, small slot size, low slot velocity, high sweep velocity, survival after impingement or screen contact) confers some degree of protection to the affected life stage, although the precise quantitative degree of protection provided by each cannot be established. Organisms outside the HZI (e.g., near bottom, near surface, in shoals) would not be subject to encounters with the intake screen. However, the proportion of organisms that may occur in those locations cannot be predicted, and turbulent mixing of waters could result in organisms being moved throughout the water column. Thus, we consider the HZI to have a positive but limited contribution to protection. The greatest contributions to protection from screen effects are provided by the high sweep velocities generated by tidal currents and the low slot velocities. On average, sweep velocities twice the maximum through-slot velocity will occur about 85 percent of each tidal cycle, and through-slot velocities will average well below the design maximum. Analyses by Alden of study data project that exclusion as high as 100 percent can be achieved with wedgewire screens operated as proposed for KWR, when through-slot velocities are low and sweep velocities are relatively high. Thus, sweep velocities, while variable, will provide a high degree of protection from both contact with the screen and impingement on the screen. Small slot widths prevent larger organisms from passing into the intake system, and low through-slot velocities ensure that organisms greater than about 10 mm in size would be capable of escaping from screen contact and impingement.

5.2.3.8 Consideration of Population Level Impacts

A major issue in the previous VMRC KWR permit hearing was what the consequences to the adult population would be of KWR-induced losses of American shad early life stages. Debate concerning population-level significance of losses of early life stages is not unique to the KWR, and has been extensive over decades of regulatory proceedings regarding the consequences of power plant water withdrawal-induced mortalities to early life stages of fish. Such debate arises as a result of many scientific uncertainties, including such factors as biological differences among fish populations in different geographical regions and compensation, the possibility that anthropogenic loss of early life stages may be offset by density-dependent increases in survival of the remaining individuals (Rose et al. 2001). Any attempt to quantitatively and reliably project effects of early life stage losses to adult population levels would require data and information not currently available for the Mattaponi River American shad population. Thus, as requested by the RRWSG, the Panel sought to develop a pumping hiatus that would provide nearly complete protection to vulnerable early life stages, and thus avoid early life stage losses and obviate the need to assess their population-level significance.

However, there remain two circumstances under which vulnerable life stages could be subject to impingement and entrainment effects from the KWR as currently proposed: 1) when present in the vicinity of the intake outside the pumping hiatus period in years of normal operation; and 2) under drought emergency conditions, when a pumping hiatus is not implemented. The protocol for development of temperature triggers for the pumping hiatus described in Section 5.2.2 is intended to ensure that less than 3 percent of the standing crop (based on weekly densities) of American shad eggs and yolk-sac larvae would occur outside the period of the pumping hiatus. Thus, only a very small portion of the eggs and yolk-sac larvae in any year would be potentially exposed to any intake effects. As we have repeatedly noted in this report, each of the protective layers contributes to protection, but the degree of protection cannot be rigorously quantified. However, considering the substantial contribution of predominant sweep velocities, and lesser contributions from all of the other layers, we believe that the probability of significant early life stage losses of American shad is vanishingly small.

Regarding the second circumstance, the projected likelihood of a spring drought emergency declaration occurring is expected to be zero over the next several decades and about 2 in 74 years once water demand has reached projected levels for the year 2040 (see Section 2.3.2 and Appendix F). Climate change predictions, while uncertain, suggest the possibility of increased droughts and floods for the mid-Atlantic region. Increased floods could result in reservoir capacities remaining sufficiently high to preclude declaration of drought emergencies in subsequent years of low precipitation. However, more frequent droughts could result in a higher frequency of drought emergency declarations than would be predicted based on the past 74 years of flow data, and several consecutive years of drought emergency under which withdrawal would be permitted would represent a potential worst case scenario with regard to consequences to the American shad population. However, in any year in which withdrawals would be permitted, vulnerable life stages would be protected by all of the protection layers beyond the hiatus, as was discussed for vulnerable life stages present outside the hiatus period. Under a drought emergency declaration, withdrawals would only be allowed if they could be implemented in compliance with VDEQ permit conditions, in particular the MIFs. As was discussed in Section 2.3.2 and shown in Table 2-3, the MIFs would significantly restrict the amount of withdrawal in most spring months of drought emergency years. The degree of restriction is greatest (as much as 86 percent reduction from maximum allowed pumping rate) in years of low flow, which would be the likely condition if several drought years were to occur in succession. All other protective attributes of the intake screen would continue to contribute to enhanced protection. As noted above, uncertainties preclude reliable quantification of the degree of protection, but all information reviewed suggest that the cumulative level of protection is very high.

The RRWSG anticipates that entrainment monitoring will be required as part of their VDEQ Water Protection Permit-mandated biomonitoring program. In anticipation of that requirement, the Panel was instructed to develop a design for reliable entrainment monitoring to be performed once the intake becomes operational. The program recommended by the Panel is described in detail in Appendix D. Entrainment sampling would be accompanied by sampling throughout the American shad spawning region, in order to allow estimation of the proportion of the standing stock of eggs and yolk-sac larvae that are entrained. Entrainment monitoring would be conducted in any year in which the spring pumping hiatus is suspended. Data from such a program will provide a means of verifying the protection levels that are anticipated, reducing further any uncertainties regarding the magnitude of losses of vulnerable early life stages.

What remains at issue then is the potential consequence of small losses of vulnerable life stages of American shad during infrequent drought emergency years. Data are not available that would allow quantitative estimation of effects of early life stage losses on adult population levels of the Mattaponi River American shad population, estimates of the magnitude of the losses needed for such quantification would be highly uncertain, and there is no basis for predicting the potential frequency of years in which spring drought emergencies would be declared, beyond that used in developing the 2 in 74 year estimate. In addition, the consequences of those losses would also be dependent on the status of the population at the time the losses occurred; small losses would only be of significant concern if the population were at depressed levels. For all these reasons, only professional opinion can be offered regarding this specific issue. Any impact to a population that occurs with as low as or lower than a frequency as 2 in 74 years would be unlikely to have a significant effect on the long-term sustainability of a species such as American shad. Individual annual spawning runs are comprised of multiple year classes, and the sizes of yearclasses vary substantially in response to annually varying environmental conditions during the spawning period (Crecco et al. 1983). Also, the York River shad population exhibits some degree of iteroparity, meaning that adults may survive spawning and spawn multiple times. Walburg and Nichols (1967) reported York River shad repeat spawners averaged about 20 percent of annual spawning runs. Olney and and McBride (2003) reported that 50 percent of the twelve York River females they used in their study were repeat spawners. Based on these factors, the effect of any impact to a single yearclass is dissipated as it is spread across multiple future spawning seasons. This ameliorates the long-term effects of any impacts that may occur during isolated drought emergency years. Safe yield modeling using the existing 74 year data record for Mattaponi River flows showed no occurrence of drought emergencies in springs of consecutive years. USEPA predictions of increased frequency of floods and droughts are specified as being uncertain. The information available to the Panel suggests that a worst case scenario of multiple successive years in which drought emergencies existed in spring, and when spring withdrawals would be permitted, is a very low probability event. Even were it to occur, the layers of protection described above would result in very low levels of losses of early life stages, which would be of significance only if the American shad population were at a depressed level. Taken together, these factors suggest that the suspension of the spring pumping hiatus in drought emergency years does not pose a significant risk to the American shad population.

5.3 OPERATIONAL EFFECTS - SALINITY CHANGES

Concerns have been raised about the potential for KWR withdrawal of freshwater from the Mattaponi River to alter the salinity regime in the river and thus change habitat characteristics, with resultant changes in fish populations. The proposed KWR intake location is within the tidal freshwater region of the river, and any changes in salinity of habitats due to freshwater withdrawal would be seen in the area downstream of the intake, where a change in salinity levels and location and slope of the salinity gradient might occur.

To establish whether any effects on fish may occur, it is first necessary to characterize the nature and magnitude of salinity changes that might be caused by KWR withdrawals. The simulated water withdrawals from the safe yield modeling (Appendix F and Chapter 2) can be compared to the concurrent total freshwater flow at the proposed intake location at Scotland Landing to establish the projected magnitude of change in total freshwater flow from the upper Mattaponi into the lower portion of the river. Table 5-4 shows the projected average percent of seasonal freshwater flows that would be withdrawn by KWR operating within the VDEQ Water Protection Permit withdrawal constraints, in particular the MIFs. These figures do not account for the American shad spawning period pumping hiatus, which would reduce spring percentages by about two-thirds.

For the 30 year period for which freshwater flow records are available from the Beulahville USGS gauging station, KWR withdrawals would have been, on average, less than 6.3 percent of freshwater flow at Scotland Landing throughout the year. For 50 percent of the time period, withdrawals would be less than 4.8 percent of freshwater flow. Withdrawals would be less than 10.9 percent of freshwater flow for 75 percent of the time. Such relatively small withdrawal volumes are unlikely to significantly alter the freshwater hydrology and salinity regimes within the lower Mattaponi River.

Table 5-4. Projected seasonal KWR water withdrawals, from Table expressed as a percentage of total freshwater flow at Scotland Landing (from ASA 2003).

Season	Average	Median	Upper Quartile
Winter	2.7 %	0.9%	4.2%
Spring	4.1%	2.2%	4.6%
Summer	5.1%	3.4%	7.6%
Fall	6.3%	4.8%	10.9%

Hydrodynamic modeling was conducted by Hershner et al. (1991) to quantify the magnitude of those alterations. However, since this modeling was conducted, the reservoir project has been scaled down in size, and more stringent MIF requirements have been imposed. Thus, RRWSG informed the Panel that the water withdrawals incorporated into the modeling are approximately three times the magnitude of withdrawals that will be allowed under the VDEQ permit. Hershner et al (1991) showed that, in the absence of any water withdrawal, low salinity brackish water is expected, on average, to intrude very little into the Mattaponi River in the spring, up to Mill Creek (RM 12) in summer, and up to Davis Beach (RM 15) in fall (see Figure 3-6 for named locations). Under extreme low flow conditions, this brackish water may intrude as far upstream as Mill Creek in spring. During summer and fall, salinities at Courthouse Landing could reach as high as 2 to 4 ppt, respectively, under these same extreme low flow conditions. Salinity modeling with the inclusion of Mattaponi River withdrawals for King William Reservoir at approximately three times currently permitted levels, found that freshwater areas of the river remained fresh and that salinity within brackish areas increased, at most, 0.1 to 0.3 ppt, depending on season. The U.S. Army Corps of Engineers Waterways Experiment Station conducted a technical review of Hershner et al (1991) and concluded that the approach taken was "…essential and technically sound" (Johnson and Wang, 1997). The Virginia Department of Environmental Quality concluded, based on the available modeling results, that the KWR water withdrawals would not significantly alter the salinity regime (Testimony of Mr. Joe Hassell, VDEQ, before the Virginia State Water Control Board, December 16, 1997). With the actual water withdrawals about one third of what were modeled, the effects of the water removals on salinity patterns within the Mattaponi River are likely to be very small and most probably undetectable, because they would be within the range of expected measurement error.

With a pumping hiatus in effect for 40 to 90 days in the spring in years of normal operation, no water withdrawal would occur and there could be no KWR-induced changes to spring salinity regimes throughout the river. Because Mattaponi River anadromous fish populations are of particular concern, special attention can be placed on potential for water withdrawals to affect nursery habitats of juveniles of the anadromous fish populations during the summer and fall periods prior to their seaward migration. Figure 2-5 showed that the MIF constraints are close to or higher than average monthly flows in low-flow years during the summer and early fall. Under such circumstances, no water withdrawals would be permissible over a substantial portion of the summer/fall period, although on a daily basis, some withdrawal would be expected to occur over periods of days when flows are above the monthly average.

This minimal nature of summer and fall water withdrawals is made further evident in Appendix F, where details of the safe yield modeling used to project water withdrawal rates under a wide range of conditions are presented. Figure 5-9, taken from Appendix F, and other figures in Appendix F, show predicted average monthly withdrawals in years following significant droughts, when normal reservoir operation would typically mandate maximum pumping to restore reservoir capacity. The conservative minimum instream flows mandated in the KWR VDEQ Water Protection Permit preclude withdrawals in many summer and fall months and when withdrawals do occur, they tend to be 10 mgd or less.

An additional level of protection against significant impacts to fish from changes in salinity regimes is provided by conditions D.3 and D.4 in the KWR Water Protection Permit. These permit conditions require the RRWSG to monitor salinity regimes so as to detect any salinity-induced changes in the spawning and nursery grounds used by anadromous fish.

Condition B.8 of the permit also states that "This permit may be modified if the DEQ determines that minimum instream flow levels resulting from the permittee's withdrawal of water are detrimental to the instream beneficial use…..," indicating that the MIFs could be made more restrictive if any impacts are observed.

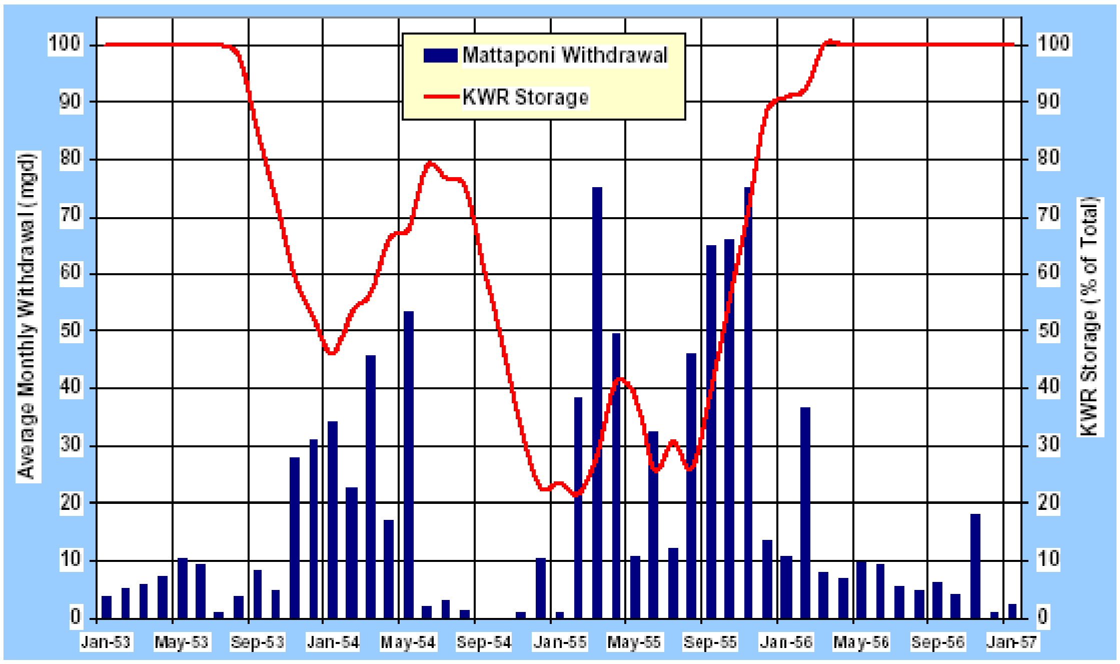

Figure 5-9. Simulated King William Reservoir storage and Mattaponi River withdrawals (Jan 1953-Jan 1957)

All of the modeling results provided to the Panel support the conclusion that the KWR water withdrawals will not substantially alter the natural salinity regimes within the Mattaponi River. VDEQ permit conditions provide for future project modification if any adverse impacts on salinity regimes are observed. With no significant change in the salinity regime, no change can be expected to occur to fish populations and communities that are present in the river. Because the Panel did not conduct an independent review of the salinity and safe yield modeling, our conclusion assumes the validity of those modeling results.

VIMS staff raised the issue of potential for ecosystem effects at the March 19 meeting with the Panel. The Panel has considered this issue from the perspective of how any such effects could be generated by the KWR project. The VDEQ permit MIFs constrain KWR water withdrawals in such a manner as to preclude significant effects to natural salinity regimes in the river, as was already noted. The MIFs also exert greatest constraint on withdrawals during periods of low flow, such as summer and fall. Largest withdrawal rates occur during periods of highest river flow. Thus, most of the water withdrawn from the Mattaponi River comes from "skimming" water off the highest inflows (e.g., pumping at maximum withdrawal rate would be likely to occur during a period of high precipitation and runoff, assuming the reservoir were not at capacity and if the withdrawal did not violate the MIF). The maximum predicted average seasonal withdrawal rate is 6.3 percent of the Mattaponi River freshwater inflow. Variations in withdrawal rates around the average will obviously occur. The maximum upper quartile value for seasonal withdrawal rate as a percentage of freshwater inflow is 10.9 percent, meaning that the percentage of freshwater withdrawal will be less than 10.9 percent for 75 percent of the time. Given that such withdrawals were not predicted to significantly alter salinity regimes in the river, and the removal of such small percentages of freshwater inflow coupled with the high population turnover rates of phytoplankton and zooplankton, the Panel concluded ecosystem-level effects would be undetectable..

5.4 OPERATIONAL EFFECTS - NOISE

There has been a recent upsurge in interest related to the effects of anthropogenic sounds in the aquatic environment, partly because of concerns for the safety and health of marine mammals (NRC 1994; Richardson 1995; Popper 2003). The sounds of boats (Scholik and Yan 2002a; Wales and Heitmeyer 2002) and seismic exploration (McCauley 1994; McCauley et al. 2003) have been of particular concern. Because the sensory receptors for sound in fish and mammals are similar, many of the concerns for damage have been extrapolated to fish. Despite concerns, aquatic animals live in a naturally noisy environment and are variously adapted to accommodate and use this sensory realm (Myrberg 1980; Popper 2003).

Fish have species-specific hearing ranges in terms of both sound frequency given in Herz (Hz; previously known as cycles per second) and volume given in decibels (dB) referenced to 1 microPascal (Figure 1). The volume reference is used to allow investigators to compare levels recorded in the aquatic environment at different places and times (see www.earthisland.org/immp/eii_sonar_chart.pdf). For comparison, the reference value in air is 20 microPacals, which is the threshold level of human hearing at 1,000 Hz. All fish that have been tested are capable of hearing (Popper 2003). Most species detect sounds in the 500 to 1,000 Hz range, with best hearing from 100 to 400 Hz. Besides hearing, many fish produce sounds and use sound for communication (Zelick et al. 1999). Popper (2003) has surmised that fishes, like most animals, glean a good deal of information about their environment from sounds that might include waves, currents, and other diverse sources.

Some species found in the Mattaponi River have especially acute hearing thresholds and sensitivity to frequencies far beyond those of most species. Species like the goldfish and catfish can detect sounds over 3,000 Hz. Most notably, fishes of the family Alosinae, including American shad and blueback herring, can detect ultrasonic sounds to over 200,000 Hz (Mann et al. 2001). These shad and herring appear to have developed such high sensitivity in order to avoid predation by marine mammals, which use high-frequency sounds for locating prey (Mann et al. 1998; Plachta and Popper 2003). The importance of these high frequencies for detecting in-coming predators is understandable when we recognize that low frequency sounds are rapidly attenuated in water and only the high-frequency sounds penetrate more than a few meters from most sources (Rogers and Cox 1988).

The sensitivity of alosines to high-frequency sound has been used to deflect these species from water intakes. Blueback herring avoided sounds of 110,000 and 140,000 Hz at source levels of 180 dB in net pens and at the Richard B. Russell Dam, Savannah River, Georgia-South Carolina (Nestler et al 1992). Broadband sound of 122,000-128,000 Hz at a source level of 190 dB successfully excluded alewife from the intake of the James A. FitzPatrick Nuclear Power Plant on Lake Ontario (Ross et al. 1993, 1996), where it is now the accepted control mechanism for minimizing fish impingement on intake screens. Sound of various frequencies is being tested and used for behavioral guidance of several fish species (Coutant 2002).

Exposure to loud noises can reduce sensitivity of a fish's hearing, analogous to the effects in humans. Sholick and Yan (2002a) demonstrated that noise from an outboard boat engine impaired the hearing of a hearing specialist, the fathead minnow. There was less effect on a hearing generalist, the bluegill sunfish (Scholick and Yan 2002b).

This sampling of the recent scientific literature confirms the need to evaluate whether a water intake on the Mattaponi River has the potential to produce sounds that could affect migrating American shad and river herring as well as resident species such as carp and catfishes. The effect likely would be most pronounced if sound is produced in the high-frequency range. Such sound, if present above background levels, could deter adult and juvenile shad and herring from passing the intake in the narrow Scotland Landing site. Even hearing non-specialists might be affected if the sounds are very loud. None-the-less, such sounds should be placed in the context of currently accepted, but demonstrably detrimental, sounds on the Mattaponi River, such as from outboard motors.

On the recommendation of the Fisheries Panel, the RRWSG contracted with Marine Acoustics, Inc. to take sound measurements at an intake similar to the KWR intake on the Mattaponi River. The intake is the raw water intake for the City of Virginia Beach, Virginia, located on Lake Gaston, Virginia. Both the proposed KWR intake on the Mattaponi River and the Lake Gaston intake use an underground wet-well design and cylindrical wedgewire screens in the source water body that are connected to the wet well by large piping. The details of the KWR intake are provided in Appendix G; the Lake Gaston intake is described briefly in Appendix H. In a wet-well design, hydraulic lift pumps draw water vertically from the concrete-lined well. The pumps are suspended in the well from an above-ground pumphouse without touching the sides or bottom. The well is connected to the receiving water by piping below the source-water elevation and fills by gravity flow. Much of the noise associated with a pumping operation is associated with water rushing through the pump's impellers and casings at high velocity. The use of submerged, vertical turbine pumps ensures that most of the sound they produce is contained inside the well. A principal difference between the two intakes is that the Lake Gaston wet well is located somewhat closer to the screens and to the source water than is the KWR pumphouse (circa 350 feet). This shorter distance at Lake Gaston would cause more intense water-borne pump sounds in the source water body, and overestimate sounds at the KWR intake. Each facility uses a periodic burst of compressed air to flush debris from the screen. Both facilities were designed to minimize noise from the pump motors, but the focus was on sound through the air rather than water, to avoid effects on human neighbors.

The pump capacities and operational characteristics at the Lake Gaston intake differ somewhat from those at the proposed KWR intake, but these differences were taken into account in planning the tests. The Lake Gaston pumping station has a 60 mgd capacity (each of five large pump delivers 15 mgd at high speed and 10 mgd at low speed). A sixth pump, operated continuously, delivers 4-8 mgd. Screens at Lake Gaston were designed with 1 millimeter openings and the maximum withdrawal velocity at the screen to not exceed 0.5 feet per second. The intake screens for the proposed maximum capacity 75 mgd Mattaponi River pumping station would be designed to have the same 1 mm slot openings, but a lower 0.25 fps maximum through-slot velocity.

To accurately create KWR-like sounds from the screens, the Lake Gaston pumps were run at 30 mgd to halve their through-slot velocity to 0.25 fps. Two types of reference sound environments were obtained, one being ambient sound levels at a distance from the intake, and the other being sounds at the intake with the minimum pumping rate we could obtain (pumping with the small, 8 mgd pump). The minimum pumping rate yielded a flow rate through the screens of approximately 0.10 fps (first trip) and 0.05 fps (second trip). For further details, see Appendix H. The general study design was to measure sounds at various points on two lines radiating horizontally from the intake (to 100 ft from the intake at the intake depth of 17.5 ft) and vertically (surface to 25 ft, one foot from the intake). Horizontal transects were sampled every 5 ft for about half the distance and then every 20 ft to a total distance of 100 ft. Vertical measurements were taken at 5-ft intervals. These measurements would establish both the source sound close to the intake and quantify the attenuation of sounds with distance from the intake. The sounds of air bursts were recorded, also, at a distance of about 150 ft from the intake (the boat location when the burst was initiated). Air-burst sound at the intake was calculated by assuming spherical spreading followed by cylindrical spreading at two times the water depth (an addition of 18 dB to the measured readings). These sounds were compared to sounds recorded at five sites not in the immediate vicinity of the intake (150 ft from the intake, two small inlets not in direct line with the intake, two sites about one quarter mile across the lake from the intake) (see Appendix H).

Two sampling trips were made, on 19-20 February and 20 March, 2004. The first trip recorded ambient noise, air bursts, and operation of one small pump operating at about 8 mgd. Equipment malfunctions caused this trip to miss recording high frequencies. A second trip was made on March 20, 2004. For this trip, the pump station operators kindly provided the needed pump operating levels and the high-frequency recording equipment functioned properly. The results showed that only the 30-second air burst created sounds that were detected above ambient sound levels at any frequency. The noise levels at the intake with the minimum pumping rate and the 30 mgd rate were indistinguishable from the ambient noise levels at the reference locations away from the intake. That is, any sound from the pumping station and the intake was less than the variation in background noise. The air burst produced acoustic energy primarily in the low frequencies, amounting to a 10 dB increase above the ambient nose in the frequency band from 110 Hz to about 2 kHz. Above 2 kHz, the airburst noise faded rapidly with increasing frequency and was within 1 dB of the ambient noise by about 12 kHz. The intake produced no sounds in the high frequencies that differed from ambient (erratic peaks of sound were seen at high frequency at both ambient and intake stations, however; Marine Acoustics staff suggested these most likely were the sounds of motor watercraft on the lake).

Based on the sound measurements at the Lake Gaston water intake, we anticipate no effects to fish from additional sounds produced by normal operation of the KWR intake. The results of the field studies indicate that there are no sounds generated at the high frequencies to which the American shad, blueback herring and alewife are especially sensitive. There may be momentary startle responses from a rapid increase in low-frequency noise due to the cleaning air bursts, which would occur infrequently. Frequency of cleaning air bursts may be as low as once per week to as much as 2 to 3 times per day, depending on site specific characteristics that may vary in response to environmental conditions and season (e.g., amount of suspended debris, such as leaves). Total duration of air burst cleaning of the screen array would be about 90 seconds for any single cleaning event. These brief and infrequent cleaning events would not result in a sustained adverse effect on normal fish behavior.

6.0 KWR MITIGATION MEASURES

6.1 BACKGROUND

A number of mitigation measures were incorporated into the KWR project. Measures to minimize construction impacts were discussed in Section 2.2. A pumping hiatus during the American shad spawning period was described in Section 5.2. Two additional mitigation measures previously proposed by the RRWSG that are not integral to the KWR project and constitute out-of-kind mitigation are discussed here.

6.2 MIGRATORY PASSAGE FACILITIES

The RRWSG worked with the Virginia Department of Game and Inland Fisheries (VDGIF) to identify fish passage mitigation measures that would be consistent with those outlined in the Final Environmental Impact Statement for this project. VDGIF identified several sites in the York, James and Rappahannock watersheds as candidates for fish passage facilities, three of which were incorporated into the VDEQ Water Protection Permit (VWPP#93-0902) for KWR. That permit reads in part "The permittee shall cooperate with the Department of Game and Inland Fisheries to plan and restore anadromous fish passage to at least one currently blocked tributary in the York River Basin. The plan shall include cost sharing provisions. The permittee shall initially investigate the feasibility of restoring fish passage to the following three sites: South Anna River, Herring Creek and Gravatt's Mill Pond." In a May 9, 2003 letter to VMRC, the RRWSG committed to an expenditure of $450,000 toward provision of fish passage facilities. The Panel was not involved in the selection of these three candidate sites for fish passage mitigation

The Ashland Mill Dam is in Hanover County on the South Anna River near Route 1. The VDGIF has designated the Ashland Mill Dam as the highest priority site for fish passage restoration in the York River watershed (VDGIF, 1998). A fishway project at this location would reopen approximately 10 miles of anadromous fish habitat. The VDGIF and USFWS had collaborated to produce a Denil fishway conceptual plan in 1993 that would have cost between $300,000 - $500,000 to install at that time. Since then, a lack of funding has kept the project from moving forward. The VDGIF Fish Passage Coordinator is exploring the possibility of resuming work with RRWSG financial support. Also under consideration is the installation of fish passage facilities at the Ashland Water Supply Dam. Providing passage at this site would restore an additional 28 miles of anadromous fish habitat.

Herring Creek Millpond is also on VDGIF's fish passage priority list. This site is located in King William County in the vicinity of Aylett. Installation of fish passage facilities at this blockage would restore 9.5 miles of anadromous fish habitat. The VDGIF Fish Passage Coordinator and the RRWSG have been investigating the viability of this project in more detail.

The third potential site for fish passage restoration is Gravatt's Millpond, which is located on Millpond Creek at the Bleak Hill Farm in King William County. Fish passage at this site would reopen 4 miles of anadromous fish habitat. Due to the identification of a promising wetland restoration site on the adjacent property, its inclusion in the Mitigation Program is logistically advantageous.

American and hickory shad, blueback herring and striped bass were found below Ashland Mill Dam in VDGIF surveys in the 1990s (Fernald 1998). American shad, striped bass and blueback herring were found in the Mattaponi River near Aylett, at its confluence with Herring Creek in surveys conducted in 1997 (Fernald 1998). All these anadromous species might use passage facilities at the three sites specified in the permit, with river herring (alewife and blueback herring) having the potential for greatest benefit. Provision of passage into impoundments and impounded portions of streams and small rivers has been a major element of anadromous fish restoration along the entire East Coast (ASMFC 1999) and within the Chesapeake Bay (http://www.chesapeakebay.net/c2k_livingresources.htm). Provision for fish passage for anadromous alosines has also been employed as mitigation in permitting of major facilities, such as power plants (PSEG 1999). Major American shad restoration programs in the Bay have involved extensive fish passage construction at dams on major rivers such as the Susquehanna and James.

The potential benefits to river herring runs that would result from provision of migratory passage has been assessed by evaluating river herring production at various locations along the East Coast. Gibson (1984) developed several statistical models to relate spawning/nursery acreage to average river herring population size, using data for both alewife and blueback herring from 18 river herring runs in Canada, Maine, Massachusetts, Rhode Island and Connecticut. The model he believed to be most appropriate ($Y = 16259.23 [\sqrt{X}] - 46311.3$, where X is acreage and Y is average annual run size) had an R^2 value of 0.687, a significant fit but with substantial unexplained variance.

PSEG (1999) analyzed similar and more recent data to develop an average production of adult river herring per acre in their projection of benefits from fish passage facilities to be installed at tributaries of the Delaware River as mitigation for the permitting of the Salem Nuclear Power Plant. They identified a production figure of 235 fish/acre used by the State of Maine in predicting potential restoration benefits. This production figure is based on commercial landings from six watersheds located in Maine during the period 1971 to 1983. The average yield per surface acre of pond habitat for the six watersheds ranged from 46 to 684 pounds per acre, an arbitrary figure of 100 pounds per acre was chosen as a conservative estimate based on those data for estimating the potential production of alewives in the Kennebec River system. Assuming an average weight of 0.5 pounds per adult and an 85 percent exploitation rate, the estimated production of alewives would be 235 adults per acre. PSEG (1999) noted, however, that the average commercial yield during the 1971 to 1983 period from these six watersheds with relatively unproductive oligotrophic lakes was actually 550 fish per acre. Assuming an 85 percent exploitation rate, they estimated that the average total production of adult alewives would be 647 fish per acre. Because it seemed reasonable to expect that the relatively productive euthrophic impoundments associated with the Delaware Estuary would produce considerably more than 235 river herring per acre, they used an estimate for total river herring production of 650 fish per acre of rearing habitat to assess potential restoration benefits.

Estimates of potential American shad production have been used in the Susquehanna River American shad restoration program as a basis for establishing the required capacity of fish passage facilities constructed at mainstem dams on that river. St. Pierre (1979) developed an estimate of 48 shad per acre to be used for that purpose, based on historical shad production figures for the Susquehanna River prior to dam construction. This figure can provide a rough estimate of the potential production of American shad that could result from provision of passage at the three dams identified in the KWR permit.

The acreage of Gravatt's Millpond and Herring Creek Millpond were estimated from USGS topographical maps using GIS. The acreage of the 10 miles of impoundment upstream of the Ashland Mill Dam was also estimated. Table 6-1 presents the estimated acreage and the river herring production estimates derived using the methods of Gibson (1984) and PSEG (1999). It is evident that the Gibson (1984) equation yields estimates substantially greater than the PSEG(1999) approach. The estimates of potential American shad production using St. Pierre's (1979) production figure are also presented. All these estimates have a substantial degree of uncertainty inherent in them, but confidence limits around any single projected value cannot be calculated. Also, these figures represent predicted long-term average production levels, and substantial annual variation in run size would be expected. However, the estimates are based on the best data and information available and are reasonable estimates of the potential long-term benefits of provision of passage at the three dams evaluated.

Table 6-1. Estimated average annual river herring and American shad production that would result from provision of fish passage at the sites indicated

Site	Estimated Acreage	Gibson(1984) Herring Estimate	PSEG (1999) Herring Estimate	St. Pierre (1979) American Shad Estimate
Ashland Mill Dam	124.5	135,108	80,925	5,976
Gravatt's Millpond Dam	19.6	25,671	12,740	941
Herring Creek Millpond Dam	19.8	26,038	12,870	950

The RRWSG has also offered to provide an additional $250,000 in funding to implement fish passage improvements at roadway culvert blockages within the York River Basin in support of the Chesapeake 2000 Bay program Agreement signed by the Governor of Virginia and the 1999 National Fish Passage Program administered by the U.S. Fish and Wildlife Service (USFWS). Culverts to be improved would be selected by VDGIF in cooperation with the USFWS and the Virginia Department of Transportation (May 9, 2003 Letter from City of Newport News Waterworks to VMRC). Provision for fish passage through currently impassable culverts would open new spawning grounds to anadromous fish species such as river herring, white perch and yellow perch.

One of the goals of the Chesapeake Bay Program's fish restoration program is to increase the number of stream miles open to anadromous fish migration. However, the Chesapeake Bay Program has not developed estimates of increases in populations that may result from providing access to additional miles of streams. River herring as well as white and yellow perch, are well known to spawn in very small streams, access to which is often blocked by culverts. Herring larvae produced in such streams drift downstream and by the time they reach the lower portions of streams, they have absorbed their yolk sac and begin to feed on their own. Field data indicates that they continue to move downstream into slow moving waters, impoundments and/or freshwater tidal nursery areas, where they may remain until their seaward migrations in late summer and early fall (J. Mowrer, MdDNR, pers. comm.). White and yellow perch early life stages are likely to exhibit similar behavior. While providing passage through culverts will create new areas for spawning, it is unlikely to create new nursery areas. There are no data or literature that provide a basis for quantitatively estimating increases in population size under such circumstances. The additional larvae produced in small streams may not result in population increases when nursery areas are already at carrying capacity, but they would clearly enhance total production under any other circumstance. Thus, improving fish passage through culverts is definitely a desirable mitigation measure, but its fish population level benefits cannot be estimated.

The USFWS has expressed interest in provision of passage for American eel at dams throughout the East Coast of the U.S. to help reverse the continental decline in populations of this fish species (Haro et al 2000). The RRWSG's proposals to provide funding for improved fish passage at both dams and culverts are likely to enhance upstream passage of juvenile American eels (elvers) at the locations where improvements are made. At any of the three dams identified as priorities by VDGIF, passage facilities specifically designed for American eel passage would be of greatest benefit for that species. It is not possible to estimate the potential benefit to American eel populations from passage improvements. It should be noted that decisions on the appropriate type of passage facilities to construct and where they are to be constructed are the responsibility of VDGIF, with the RRWSG only providing funding for those facilities.

6.3 HATCHERY MITIGATION

In a May 9, 2003 letter from Brian L. Ramaley, Director of City of Newport News Waterworks, on behalf of the RRWSG, to Mr. Tony Watkinson, Deputy Chief Habitat Management, VMRC, a list of KWR permit conditions was proposed that included a number of fish mitigation measures. Condition 3 (Shad Hatchery Mitigation) was an offer to produce 1 million juvenile American shad for release annually into the Mattaponi River (later clarified to mean 1 million American shad larvae) to help replenish the Mattaponi American shad population. RRWSG indicated to the Panel that the proposed hatchery mitigation was intended to compensate for any potential loss of American shad early life stages that would be caused by the KWR water intake. The anticipated outcome would be to ensure that the project would have no net impact on American shad and would not impede the recovery of the Mattaponi River population.

A number of concerns regarding hatchery mitigation were raised at the VMRC KWR permit hearing. One key concern is that hatchery augmentation could result in genetic bottle-necking (i.e., a reduction of genetic variation associated with low number of breeders) in the population being augmented. A decrease in genetic diversity of a population is generally considered to result in decreased fitness. Domestication selection (i.e., the adaptation of a species to an artificially regulated environment) begins immediately through enhanced survival of genotypes that would otherwise perish in nature, and increases during each successive generation in which such artificial population augmentation may occur (Busack and Currens, 1995; Waples 1999). Other issues relating to this proposal would be the source of the required number of brood stock (given the depleted condition of the Mattaponi River American shad population), where, how and when the larvae would be reared, and when and where the larvae would be released.

Given that the project as now proposed includes a pumping hiatus during most of the American shad spawning period and that the intake screens provide a high level of protection to early life stages when pumping is occurring, the Panel concluded that the hatchery mitigation proposal was no longer needed to ensure no net impact to American shad, and that the potential for adverse consequences outweighed the potential benefit to the Mattaponi River American shad population. The Panel thus recommended that that proposed mitigation measure be dropped from the project.

The Panel does recognize, however, that hatchery programs have proven to be an effective means of restoring American shad to rivers in which populations were extirpated in the past, examples being the James River in Virginia, the Lehigh River in Pennsylvania, and the Susquehanna River, which spans the states of Maryland, Pennsylvania and New York (ASMFC 1999). In all such restoration programs, however, the intent is the establishment of self-sustaining populations that would not be dependent on hatchery augmentation in the future.

While the proposal for production and release of 1 million American shad larvae into the Mattaponi River was withdrawn, the RRWSG still includes in their overall KWR project proposal the offer to provide funding of $300,000 each to the Mattaponi Indian Tribe and the Pamunkey Indian Tribe for improvements and enhancements to their American shad hatcheries. The Indian tribes have a long history of hatchery augmentation of Mattaponi and Pamunkey River American shad populations. The RRWSG has also indicated that if the tribes decline those offered funds, a similar level of funding would be provided to VDGIF for use in their shad hatchery programs. The Panel has not evaluated these programs and offers no opinion on their merits or detriments.

7.0 FINDINGS OF PANEL

7.1 POTENTIAL FOR IMPACTS TO FISH FROM CONSTRUCTION

- Construction is prohibited between February 15 and June 30, which encompasses the majority of the spawning period for the anadromous and most spring-spawning resident species that inhabit the Mattaponi River. Thus, impacts to the majority of the early life stages of spring-spawning species as a result of construction activities cannot occur. Dredging for placement of the intake screen supports will be conducted within a sheet pile enclosure, and loading of dredged sediments into transport barges will be done within a temporary turbidity curtain. Dredged sediment will be disposed of in a permitted disposal facility at Craney Island. These procedures will result in minimal dispersion of suspended sediments and turbidity. No significant impacts would be expected from such minimal environmental perturbation.

- Placement of the KWR intake structure in the Mattaponi River is analogous to placement of any hard structure (e.g., pier, dock, bridge abutment, artificial reef) in a portion of a water body in which none had previously existed. In freshwater systems, such structure results in fish aggregations. Such aggregations may make fish more vulnerable to exploitation by fishermen. The intake would not hydraulically create concentrations of non-motile life stages (e.g., eggs and larvae) except during infrequent slack tide periods. While both forage fish and predators may concentrate in the vicinity of the structure, those concentrations would result from redistribution of existing populations. The creation of increased densities of predators and prey may result in some increase in predation rates, because of their enhanced proximity, but it is the opinion of the Panel that any such increase would likely be small and most likely inconsequential within the context of the Mattaponi River ecosystem.

7.2 POTENTIAL FOR IMPACTS TO FISH FROM INTAKE SCREEN EFFECTS (ENTRAINMENT, IMPINGEMENT AND SCREEN CONTACT)

- The fine mesh size (1 mm) and low through-slot velocities that will occur at the KWR wedge-wire screens (<0.25 ft/sec) eliminate potential for impingement of juvenile and adult stages of nearly all fish species; only very small and immotile or barely motile life stages (e.g., eggs and very early life stages) have potential for experiencing screen effects (i.e., entrainment, impingement and screen contact).
- Three attributes of spawning behavior (reproductive guild, reproductive habitat, and egg distribution) were used to screen 35 species comprising the Mattaponi River fish community to identify species with early life stages with the greatest likelihood of occurring in the water column in the vicinity of the KWR intake (i.e., vulnerability to encountering the intake). Three additional attributes of reproduction (egg diameter,

length of pro-larvae, and length of post-larvae) were then used to evaluate the relative vulnerability of those species to entrainment and impingement . The vulnerability assessment identified a group of vulnerable species that was consistent with but somewhat broader than the groups of vulnerable species identified in prior impact assessments by VIMS and ASA. Species of concern included: American and hickory shad, river herring (alewife, blueback herring), white perch, yellow perch, and striped bass.

- The RRWSG instructed the Panel to develop a means of establishing a pumping hiatus that would, with a high degree of reliability, encompass the period during which vulnerable early life stages of American shad would be present in the vicinity of the KWR intake. Insufficient American shad early life stage and temperature data were available from the Mattaponi River or from other Chesapeake Bay tributaries to allow evaluation of potential triggers that could be used to define a hiatus appropriate for protecting American shad. Appropriate data were available from a 30-year sampling program in the Hudson River that could be used as surrogate data for trigger and hiatus development. Eggs and yolk-sac larvae were identified as the vulnerable American shad early life stages that required protection. Temperature was identified as the best trigger for a hiatus because it is easily measurable and a highly reliable indicator of presence of vulnerable life stages.
- Exploratory analyses, based on Hudson River data, showed that ceasing pumping when water temperatures reached 10 ^{o}C and restarting pumping when water temperatures reached 22 ^{o}C would provide absolute protection to 100 percent of the standing crop of yolk-sac larvae and no less than 97 percent protection to the standing crop of shad eggs in all 18 of the years for which complete data were available. The duration of a pumping hiatus defined by those temperature triggers would vary annually from 44 to 83 days, averaging 61 days. The RRWSG determined from safe yield modeling that the KWR would still be capable over the long term of meeting its water supply objectives with annual pumping hiatuses within that range.
- The Panel recommended to the RRWSG the inclusion in the project of an intensive long-term preoperational ichthyoplankton monitoring program. This program would provide 8 or more years of detailed Mattaponi River-specific data on water temperature and early life stage densities and distributions over time. Those data would then be used, following the same methods used on the Hudson River surrogate data, to establish Mattaponi River-specific temperature triggers that would define the pumping hiatus period.
- The Panel decided that feasible criteria for levels of protection, based on results of analyses of Hudson River data, would be a minimum of 97 percent protection of the standing crops of eggs and yolk-sac larvae in 7 of 8 years of study, and no less than 95 percent protection of the standing cropss of eggs and yolk-sac larvae in any single year. To further reduce potential for uncertainty, the Panel has recommended that RRWSG commit to implementation of a pumping hiatus over a temperature range of at least 12 ^{o}C, corresponding to the range between the temperatures of 10 ^{o}C and

22 ^{o}C, even if results from the preoperational monitoring program suggest a smaller temperature range would achieve the protection objectives. Because of the RRWSG commitment, results of preoperational monitoring could potentially result only in an expansion of the hiatus temperature range beyond a 12 ^{o}C span. In addition, the Panel is also recommending concurrent implementation of a hatch date study on juvenile American shad, that will document the "date of birth" of juvenile shad produced in each year. These data would contribute to verifying the efficacy of the Mattaponi River-specific hiatus temperature triggers derived from the preoperational icthyoplankton monitoring surveys.

- Analysis of the surrogate Hudson River data suggest that the 10 ^{o}C to 22 ^{o}C hiatus would encompass the period when nearly all American shad eggs and yolk-sac larvae would be present, and when high percentages of early life stages of other vulnerable species would also be present in most years.
- The Panel concludes that the studies and findings are sufficient to reject the conservative assumption that wedge-wire screens of the design proposed for KWR provide no protection to vulnerable early life stages. The available literature confirms that each attribute of wedge-wire screens (hydraulic zone of influence, small slot size, low slot velocity, high sweep velocity, survival after impingement or screen contact) confers some degree of protection to the affected life stage, although the precise quantitative degree of protection provided by each cannot be established. Organisms outside the HZI (near bottom, near surface, in shoals) would not be subject to encounters with the intake screen. However, the proportion of organisms that may occur in those locations cannot be predicted, and turbulent mixing of waters could result in organisms being moved throughout the water column. Thus, we consider the HZI to have a positive, but limited, contribution to protection. The greatest contribution to protection from screen effects is provided by the high sweep velocities generated by tidal currents. On average, sweep velocities twice the maximum through-slot velocity will occur about 85 percent of each tidal cycle, and through-slot velocities will average well below maximum. Analyses by Alden project that exclusion as high as 100 percent can be achieved with wedgewire screens operated as proposed for KWR, when through-slot velocities are low and sweep velocities are relatively high. Thus, sweep velocities, while variable, will provide a high degree of protection from both contact with the screen and impingement on the screen. Small slot widths prevent larger organisms from passing into the intake system, and low through-slot velocities ensure that organisms greater than about 10 mm in size would be capable of escaping from screen contact and impingement.
- Safe yield modeling results provided by the RRWSG to the panel indicate that the frequency of occurrence of years in which drought emergency conditions occurred in the spring, when spring water withdrawal would not be prohibited, is on the order of 2 in 74 years, based on data from 1928 to 2001 and using water demand projected for the year 2040. The RRWSG indicates that model runs using the current demand, which is about two thirds of the 2040 demand, produce no drought emergencies in the

74 years projected. Thus, probability of a drought emergency being declared in the spring is likely to be less than 2 in 74 for several decades. In drought emergency years when spring water withdrawal would be allowed, it could only be done in compliance with VDEQ permit minimum instream flow (MIF) requirements. Additional modeling illustrated that the MIFs would in most instances restrict withdrawals. The MIF restrictions resulted in monthly withdrawals ranging from 14 percent to 66 percent of the permitted maximum withdrawal rate in five of the six spring months modeled. In the one month where maximum withdrawal was projected to occur (March 1955), river flow was 630 mgd and the maximum withdrawal represented only about 12 percent of freshwater flow. Thus, spring withdrawals during drought emergencies are likely to be both infrequent and of limited magnitude. The KWR intake design provides a high level of protection from impingement, entrainment and screen contact to any relatively immotile organisms that might be present within the area of influence of the intake when water withdrawal is occurring.

- Any impact to a population that occurs with as low as or lower than a frequency of 2 in 74 years would be unlikely to have a significant effect on the long-term sustainability of a species such as American shad. Individual annual spawning runs are comprised of multiple year classes, and the sizes of yearclasses vary substantially in response to annually varying environmental conditions during the spawning period. Also, the York River shad population exhibits some degree of iteroparity, meaning that adults may survive spawning and spawn multiple times. Based on these factors, the effect of any impact to a single yearclass is dissipated as it is spread across multiple future spawning seasons. This ameliorates the long-term effects of any impacts that may occur during isolated drought emergency years. Safe yield modeling using the existing 74 year data record for Mattaponi River flows showed no occurrence of drought emergencies in springs of consecutive years. USEPA predictions of increased frequency of floods and droughts are specified as being uncertain. The information available to the Panel suggests that a worst case scenario of multiple successive years in which drought emergencies existed in spring, and when spring withdrawals would be permitted, is a very low probability event. Even were it to occur, the layers of protection described above would result in very low levels of losses of early life stages, which would be of significance only if the American shad population were at a depressed level. Taken together, these factors suggest that the suspension of the spring pumping hiatus in drought emergency years does not pose a significant risk to the American shad population. The RRWSG anticipates that entrainment monitoring will be required as part of the VDEQ permit-mandated biomonitoring program for the KWR. Such monitoring, to be implemented when water withdrawal is occurring and when early life stages are present within the area of influence of the intake, will provide a means of verifying the protection levels afforded by the design and mode of operation of the KWR intake

7.3 POTENTIAL FOR IMPACT TO FISH FROM KWR WITHDRAWAL-INDUCED SALINITY CHANGES

- Assessment of the salinity issue relied on prior modeling conducted by VIMS and safe yield modeling conducted by Malcolm Pirnie for the RRWSG.
- The major issue of concern was whether water withdrawals would alter salinity regimes in summer and fall, when the tidal freshwater portions of the Mattaponi serve as nursery grounds for important anadromous species.
- Minimum instream flows imposed on the KWR in the VDEQ Water Protection Permit often preclude and consistently restrict the magnitude of water withdrawal during most summer and fall periods, when river flows are low.
- Modeling results indicate that salinity changes would be so small as to be immeasurable, given natural variability and measurement error; given that no significant changes in salinity regimes are predicted, no consequences to fish populations would be expected.
- An additional level of protection against significant impacts to fish from changes in salinity regimes is provided by conditions D.3 and D.4 in the KWR Water Protection Permit. These permit conditions require the RRWSG to monitor salinity regimes so as to detect any salinity-induced changes in the spawning and nursery grounds used by anadromous fish. A comprehensive monitoring program will provide a basis for confirming the predictions of no significant salinity changes predictions.

7.4 POTENTIAL FOR IMPACT TO FISH FROM NOISE

- Because no data were available to address this issue, the Panel recommended to RRWSG that a sound survey be conducted at a water intake with a design very similar to that proposed for KWR. Based on the sound measurements at the Lake Gaston water intake, we anticipate no effects to fish from additional sounds produced by normal operation of the KWR intake. The results of the field studies indicate that there are no sounds generated at the high frequencies to which the American shad, blueback herring and alewife are especially sensitive. There may be momentary startle responses from a rapid increase in low-frequency noise due to the cleaning air bursts, which would occur infrequently. Frequency of cleaning air bursts may be as low as once per week to as much as 2 to 3 times per day, depending on site specific characteristics that may vary in response to environmental conditions and season (e.g., amount of suspended debris, such as leaves). Total duration of air burst cleaning of the screen array would be about 90 seconds for any single cleaning event. These brief and infrequent cleaning events would not result in a sustained adverse effect on normal fish behavior.

7.5 EVALUATION OF MITIGATION MEASURES

- Intake construction procedures and the spawning season pumping hiatus are impact avoidance measures that have been incorporated into the project as presently proposed.
- A previous offer by the RRWSG to produce 1 million shad larvae to mitigate for any water withdrawal-related impacts to the American shad population was considered unnecessary due to the imposition of the spawning season pumping hiatus; in addition, concerns about genetic bottle-necking contributed to the Panel's recommendation to RRWSG that this mitigation measure be dropped.
- An evaluation of the RRWSG offer to fund fish passage construction at stream blockages within the York River watershed indicated that this measure could increase annual anadromous fish production in the watershed, in particular for river herring and American shad.

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