Final Peer Review Summary Report

External Peer Review of Woody and O'Neal 2010 (*Fish Surveys in Headwater Streams of the Nushagak and Kvichak River Drainages Bristol Bay, Alaska, 2008-2010*) and Woody and Higman 2011 (*Groundwater as Essential Salmon Habitat in Nushagak and Kvichak River Headwaters: Issues Relative to Mining*)

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I. INTRODUCTION

In May 2012, the U.S. Environmental Protection Agency (EPA) released a draft report entitled *An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska*. The purpose of this report was to put forth a prospective risk assessment of large-scale mining in the Bristol Bay watershed, focusing on a specific case study for a hypothetical but realistic mine scenario at the Pebble deposit. Specifically, the assessment examines how future large-scale mining may affect water quality, habitat, and salmon fisheries in the Bristol Bay watershed. During preparation of this draft assessment, EPA identified the following two reports developed by non-EPA scientists that contained information relevant to this topic, but were not included because they had not been peer-reviewed: *Fish Surveys in Headwater Streams of the Nushagak and Kvichak River Drainages Bristol Bay, Alaska, 2008-2010* (Woody and O'Neal 2010) and *Groundwater as Essential Salmon Habitat In Nushagak and Kvichak River Headwaters: Issues Relative to Mining* (Woody and Higman 2011).

The purpose of this letter peer review is to determine if the information contained in these reports is of sufficient scientific quality and credibility to be incorporated into EPA's revised Bristol Bay report.

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II. PEER REVIEW OF WOODY AND O'NEAL 2010 REPORT

II.1 Charge Questions

1. Are the conclusions of the report well-supported by the evidence provided? Why or why not?

2. What are the strengths and weaknesses of the Woody and O'Neal 2010 report, in terms of:

    a. Methodology?

    b. Results and conclusions?

3. Are there important limitations or uncertainties associated with applying results from the Woody and O'Neal 2010 report to the EPA assessment? If so, what are they?

II.2 General Impressions

Michael R. Donaldson

This report documents the results of fish surveys in headwater streams in two Alaskan river drainages between 2008 and 2010. The rationale for selecting these locations was to document the presence of anadromous salmon species as well as other fish species and to collect habitat characteristic data. For fish surveys, electrofishing, trapping, and aerial surveys were conducted to determine species composition and abundance. The habitat quality data included assessments of temperature, turbidity, conductivity, pH, oxygen content, substrate type, and various other stream characteristics. The context, methods, and results appear accurate and are clearly communicated in text, figures, and tables. The conclusions align with the stated objectives and appear sound given the methods and results that were presented.

James M. Helfield

This report provides clear and convincing evidence for the widespread presence of anadromous Pacific salmon and other species important for subsistence and recreational fisheries in headwater streams within and near areas proposed for mine development. Particularly compelling is the fact that the surveys described in this report led to the nomination and acceptance of 168 km of previously undocumented streams for inclusion in the state of Alaska's Anadromous Water Catalog (AWC), which lists waterways that merit protection because of their importance to anadromous fishes. This report is conservative in that the surveys described cover a relatively small subset of headwater streams in the area and are limited to small, shallow tributaries during low flow conditions. Consequently, the report's conclusions likely underestimate the abundance and ubiquity of anadromous fish within areas likely to be influenced by mining claims.

Dennis L. Scarnecchia

The main objective of the report was to assess, in a general way, landscape-level distribution of both resident and anadromous species, with emphasis on salmon, in relation to areas proposed for potential mining activity. Emphasis was not on abundance, but on presence/absence, especially in small tributaries. The rationale forwarded was that fish distribution surveys have not been conducted in many small tributaries that, although appearing inconsequential, nevertheless may be commonly-used habitat of stocks, perhaps distinct stocks, of resident and anadromous fish at various life stages. Small tributaries are in fact often overlooked as important fish habitat. In assessing potential interaction between prospective mining activities and fish, it thus does seem highly relevant to know the distribution of resident and anadromous species in tributaries within this area. Although much other ancillary, and sometimes unnecessary, background information was presented in the report, this was the main question that was being addressed.

The information presented seemed accurate, but the presentation was not clear or well thought-out. The organization of the report was not good (including a complete lack of a discussion section and a long "conclusion" section containing new methods, results, discussion, and no

clearly stated conclusions). The science in the report was not emphasized nor articulated in very much detail. As such, the report would have benefitted greatly from more, and independent, peer review. Specific, limited conclusions regarding presence/absence of fish were adequately supported and were sound.

William J. Wilson

This report, prepared for The Nature Conservancy, documents three years of fish and water quality/fish habitat surveys of upper headwater drainage streams of the Nushagak and Kvichak River systems in Bristol Bay, Alaska. The surveys were completed during open water seasons of 2008-2010. The report documents anadromous and other fish presence in what are described as previously unsurveyed streams, and adequately documents the results of those surveys. However, parts of the Preface to the report bear little relationship to the contents of the report, making the Preface a confusing entre to the report. The Preface states that the purpose of these surveys (conducted in 2008), and by assumption the purpose of the overall report (which adds data for 2009 and 2010), was to determine if these streams and their habitat could be affected by mining activity associated with the proposed Pebble Mine. I did not see that purpose reflected in the body of the report. There was no discussion of impact assessment methodology or documentation of an environmental assessment, which would be needed to attain the stated purpose. Rather, this report is merely a data compilation of species collected by trapping, electroshocking, and aerial survey, and it presents habitat parameters for streams surveyed. The conclusions of the report are a summary of the data collected, noting fish presence in upper-drainage streams and their nomination for inclusion in the State of Alaska's Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes (Catalog). This report does not determine mine impacts as stated in the Preface. For a report documenting fish and habitat surveys in headwater streams of two river systems in southwest Alaska, the narrative and data presented accomplish this task.

II.3 Response to Charge Questions

Question 1. Are the conclusions of the report well-supported by the evidence provided? Why or why not?

Michael R. Donaldson

Yes the conclusions that the report provides new insight to fish presence and habitat quality that had previously not been available are well justified. The report provides extremely valuable information in this regard, and as the authors state, there are a number of additional tributaries in the headwaters that remain unstudied, but also require attention given the scale of the proposed mining operations.

James M. Helfield

The conclusions of this report are well supported by the evidence provided. The surveys follow widely accepted protocols and provide an accurate if conservative estimate of anadromous salmon abundance in the area. The report's conclusions (i.e., that anadromous salmon are present in streams within or near the Pebble Prospect) are indisputable.

Dennis L. Scarnecchia

As stated above, the main objective of the report was to assess, in a general way, landscape-level distribution of both resident and anadromous species, with emphasis on salmon, in relation to areas proposed for potential mining activity. The Appendix figures do depict the distribution of fish sampled (resident and anadromous) in relation to those areas. So the conclusion is supported by that data. There is no discussion section at all where results are qualified and discussed, and the conclusion section has an array of new methods, results, and discussion, with no specific conclusions identified. A much better job could have been done in methodically showing how the scientific results were obtained and the conclusions arrived at. However, the conclusion regarding fish presence/absence was supported by the data presented.

William J. Wilson

The conclusions of the report are meagerly supported by the evidence provided. The described surveys conducted during three summers in the study area show anadromous fish presence in habitats of some headwater streams in the Nushagak and Kvichak River drainage systems. The evidence presented includes documentation of fish species collected and identified by biologists who also obtained voucher specimens/photographs that were verified by field lab corroboration where appropriate. The supporting data verifying fish presence in the sites sampled are described, but in some instances the data are few; for example, in 2008 only five days of surveys were completed, and it is unclear which sites were visited in 2008 versus the next two years; data for only a total (97 sites) is provided. And the main body of the report does not include a summary of fish collected and identified at each of the sites visited in each of the years surveyed. A sampling data summary is provided as an insert to Appendix I that shows the number of reaches sampled and their total lineal length, but a mathematical error adds confusion (reaches

sampled in the three years were 4, 34, and 20 totaling 58, not 68). How does this number, 58, relate to the 97 sites mentioned on page 16? Appendix I states that 58 reaches were nominated for inclusion in the Catalog; it is unclear how "nomination" reaches relate to the total number of reaches/sites studied. I am left with some fairly simple questions that are not answered in the report: How many fish of each species were collected in each of these 58 reaches/97 sites? Were the fish located in certain parts of these reaches and not in other parts? Are "sites" the same as "reaches" in the descriptions of results? Were any sites visited in 2008 revisited in the two subsequent years? Which of the study reaches/sites are within the geographic area slated for mine development? I assume that the data collected and presented to the State of Alaska, and their acceptance for inclusion in the Catalog for 2008 and 2009, are evidence that the State accepts that anadromous fish inhabit the survey sites/reaches sampled in those years. I see no compelling reason to conclude otherwise, but the details aren't provided in this report.

Question 2. What are the strengths and weaknesses of the Woody and O'Neal 2010 report, in terms of:
a. Methodology?
b. Results and conclusions?

Michael R. Donaldson

a. Methodology?

The methods are well documented and represent standard methods for fish and fish habitat surveys. Although different methods were used for different habitats depending on whether or not the tributary was wadeable, it appears as though efforts were made to catalogue as many tributaries as possible. The methods state that study sites were selected near or adjacent to mine claims for streams with <10% gradient, but it is not immediately clear if all of these potentially affected sites were surveyed or only a subset since the maps included in the report show the study areas at a fairly coarse scale.

b. Results and conclusions?

The results provided here are well described and the conclusions seem justified. It appears that the surveys were conducted using the best available methods. The authors have identified important fish habitat and found that provided new information on anadramous salmon presence that was previously not known but instead only speculated. One potential weakness is that the surveys were conducted at only one time point at each location, which may in fact lead to an underrepresentation of the abundance and diversity of fish species present. The habitat quality data is consistent with similar data from the literature for salmon habitat in Alaska and provides important baseline data even though it was collected at only one time point.

James M. Helfield

a. Methodology?

The main strength of this report's methodology is its use of standard, widely accepted protocols to survey fish abundance at study sites. A weakness is the assessment of physical habitat at study sites, which could have been more thorough (e.g., through more extensive data collection at multiple transects across each study reach). A more detailed data set might lend itself to more extensive characterization of the relationship between salmon abundance and physical habitat, which could potentially be used to estimate salmon abundance at unsurveyed sites.

b. Results and conclusions?

The report's main conclusions (i.e., that anadromous salmon are present in streams within or near the Pebble Prospect) are indisputable. Nonetheless, the specific results of surveys at specific sites could be presented more clearly in some places. For example, it is not immediately clear how the 108 sites described on page 14 differ from the 97 sites described on page 16. Similarly, the spatial data presented in appendices I – VI could possibly be made clearer if

summarized in a table or graph. The report's conclusions would also be strengthened by some updated information to indicate whether the 2010 AWC nominations have been accepted. These are relatively minor criticisms and do not detract substantively from the report's conclusions.

Dennis L. Scarnecchia

a. Methodology?

Strengths:

The use of electrofishing. Overall, the methods used to obtain information on presence/absence and distribution of salmon seemed appropriate. Electrofishing and traps were the preferred methods. Electrofishing is less species selective than most fishing gears.

Weaknesses:

The study is not close to optimally designed, nor are the methods, results, discussion, and conclusions well presented in an organized, sequential way. The science in the report was instead embedded within considerable, often miss-placed, background information. Many of the most important aspects of the methods, such as the study design (e.g., landscape-level selection process for streams to be sampled, fish identification approaches, assignments to life history stages, such as juvenile, adult, etc.), were glossed over while other methods (e.g. excessive details of electrofishing) were overemphasized for a simple presence/absence study.

It was not clear if there was a systematic sample design for identifying exactly which streams were sampled, and why they were chosen over other possible streams (other than gradient). Although this study appears to be preliminary in nature, presumably to be followed by more detailed studies, it would have been useful to know why particular streams were chosen or not chosen in a landscape context, for example, based on their location, accessibility, or proximity to proposed mining, etc.

Accurate identification of species seems crucial in this study, but the details used for identifying particular life stages of various species seemed to be glossed over. Which keys and criteria were used to identify the various species? More detail on this would have improved the manuscript.

Although considerable information on electrofishing configuration was presented on page 12, it was not made clear what the objective of the optimal electrofishing configuration was. If the intent was to make sure that fish in a stream were able to be sampled, then a higher setting might be called for. If the intent was to avoid killing or harming any fish, then a lower setting might be called for. It would have been useful to clearly identify how the electrofishing settings matched the objective/goal of the study, for example, to make sure that if fish were in a section, that they were sampled.

Similarly, there was little said about the traps, and vulnerability of various species to traps, which can be very species selective.

Although habitat was assessed, there was little indication as to what the hypotheses of the investigators were regarding the relations between habitat measures and fish presence or absence. As it was written, it was not clear exactly why most of the habitat information was collected, other than to show they were within very general acceptable ranges for species in question.

b. Results and conclusions?

Overall, based on the limited information and methodologies forwarded, and its cumbersome presentation, the data presented showed that a high fraction of streams that were sampled within the area contained resident and anadromous fish. Nearly all streams sampled contained fish and about 74% contained salmon. Although the process for selecting the streams was not identified, many of these stream locations were within the proposed mining area, are fed by smaller tributaries within the proposed mining area, and thus stand to be potentially effected by activity.

Although presence/absence seemed to be the objective of the sampling, it would have been useful to give an indication of relative abundance of captured fish stream by stream, not just as a whole, as was done. Too little emphasis was put on the results of the fish sampling, which was the theme of the paper. It would have also been useful in a discussion section to show how the catches of anadromous fish and resident fish related to specific habitat conditions; this was not done.

It seemed inappropriate to discuss which streams have been added to the Anadromous Waters Catalog (AWC) in the results. This is more of an outcome worth mentioning at the end. The main issues for the results should probably be results regarding species distribution in relation to habitat and area, to be discussed in a discussion section.

The conclusion section as a whole presented a challenge as written because it is not a conclusion section. Conclusion sections in short scientific papers are generally a short paragraph or a list of bulleted items arrived at after scientific results have been discussed and qualified. That typical sequence was not followed in this paper. Instead, nearly all of the 4-page conclusion section consists of more background, considerable methods, results (including new data), and discussion, much of each not found anywhere else in the main paper. There is actually no designated or identified "Discussion" section, which is where the results would optimally have been discussed, qualified, and evaluated in relation to the literature. There are at least 8 references to scientific literature in the conclusion section, which is what is expected in a discussion. No conclusions are identified. Ideally, the conclusions would have emanated from a well-crafted discussion section.

So, in order to evaluate if the conclusions were based on sound scientific evidence, it was first necessary to find and articulate the actual conclusions, which were embedded within the 4-page conclusion section and in the Appendix. What were the conclusions? The conclusions are most clearly shown to this reviewer in the Appendix figures, which show the overlap among resident fish and salmon and areas proposed for potential mining activity. The authors concluded that there was an overlap and that a high very high fraction of the streams within the proposed area, certainly the lower gradient streams that they evaluated, will have fish in them and that about

75% of them will contain salmon. That conclusion is scientifically supported in this work. It would have been far preferable if the authors had put the Appendix figures in the main body of the paper and included a detailed Appendix table where they showed, as a minimum, a detailed species list, and possibly relative or ranked abundance by each stream sampled.

Although there are some limitations in the scientific design, including non-random selection of streams on the landscape and non-random attributes of streams (e.g., gradient), and also clearly in the presentation and organization of the report, overall, the science in this report supports the above presence/absence conclusion.

William J. Wilson

The strengths of this report include adequate documentation of survey methodology for fish collection and identification, although the report does not provide a description of or reference to the fish key that was used to verify species. Habitat characteristics of the sites are helpful additions to the report. I found it helpful that the report provided stream dimensions including wetted width observed during the survey, discharge, and predominant sediment composition. The report notes in several places that further studies and surveys could generate other useful information for further characterizing the importance of habitats in the study area; these statements made by observers who have spent time in the field and in the office may be helpful guides to additional field study in the future. The maps provided in the report and appendices help identify the areas surveyed.

Weaknesses of this report include a disjointed and advocacy-laced Preface, which unfortunately sets the scene for a report that bears little resemblance to that Preface. Another concern is the lack of quantitative information on number of fish collected, by species, in each reach/site, in each year, by each sampling method. For example, page 16 states that of the 97 sites surveyed, 72 contained anadromous salmon, but was that one or two fish per site, or hundreds per site? Each map that presented data could have included the location of the Pebble Mine ore body, and the area to be disturbed during the mining activity; this would have helped put into visual context the location of streams surveyed relative to the mine site (it is shown as a shaded oval on only two Appendix maps). Other weaknesses/editorial concerns for this report are provided below.

Additional Comments

- Dr. Robert Hughes is mentioned as a reviewer in the Acknowledgements; I believe Bob is at Oregon State, not the University of Oregon.
- On page 1 the survey methods are listed; given the expense of helicopter transport, it might have been useful to have also employed other methods to observe fish, including foot surveys, carcass survey/counts, or small seine deployments at some sites, or at least mention why such methods weren't employed.
- The report mentions "the continuing dramatic decline" of [salmon] in the Fraser River in British Columbia; this impression of dramatic decline in the Fraser is out of date and should be revised.

- Figure 6 states that hatcheries can cause detrimental genetic and ecological changes in wild salmon populations; hatchery effects on salmon are not the subject of, nor discussed in, the narrative of this report, and this statement is irrelevant.
- In several places, the report mentions "essential" fish habitats in Bristol Bay; this term has specific Federal regulatory meaning and should not be used as it has been in this report without reference or definition.
- The methods do not state how study sites were selected other than a passing mention of GIS mapping. Were these opportunistic visits constrained by where a helicopter could land, or were there other criteria used to select these sites?
- Habitat measurements included temperature, DO, etc., as stated on page 13; to what level of accuracy were these measurements recorded?
- The report states that stream discharge measurements used a Marsh-McBirney current meter "calibrated at each study site"; how was that meter calibrated – with a Price (or pygmy) AA? Why was the MM current meter calibrated at every site; this is a lot of work, and suggests that the meter fell out of calibration fairly readily?
- The sediment classification scheme relied on visual categorization of substrate composition; how were stream reaches that had more than one substrate type categorized? And were there measurements or observations of particle embeddedness?
- A statement on page 23 requires considerable explanation and referencing: "As illustrated by this…stud[y], headwaters comprise a significant proportion of essential…habitat for salmon…" This report provides no justification or supporting data or analyses for this statement. Significance has statistical meaning and requires a statement of confidence; terms, "significant" and "essential", have specific scientific and/or regulatory meaning that require referencing.
- The last sentence of this report implies that small headwater streams are not afforded (or minimally afforded) statutory protection if not specifically included in the Catalog; this seems to me to be misleading; any stream containing fish, anadromous or other, likely will be afforded protection in Alaska through the environmental assessment and regulatory process and a development undoubtedly will be appropriately conditioned by regulatory agencies; I believe that it is unlikely the State of Alaska will diminish its protection of fish in a stream just because that stream is not listed in the Catalog. Field studies of streams slated for impact are generally surveyed to determine if they are fish bearing (anadromous or otherwise) before the State issues permits.

Question 3. Are there important limitations or uncertainties associated with applying results from the Woody and O'Neal 2010 report to the EPA assessment? If so, what are they?

Michael R. Donaldson

The methods used here are clearly articulated and the results of the surveys are well described. This report is highly relevant to the EPA assessment. The only slight limitations that could be taken into consideration (as described above) are that it is not immediately clear if all of the tributaries near mine claims were included or if some were not studied, the fact that the surveys were only conducted at one time point for each site, which could influence the abundance and distribution results due to seasonal differences, and that different methods were used depending on stream location although it appears that standard sampling methods were used.

James M. Helfield

There are no important limitations or uncertainties associated with applying results from this report to the EPA assessment. The results of this report are highly relevant to the assessment.

Dennis L. Scarnecchia

Since the lower gradient streams will be fed by the higher-gradient streams, some of which (an undetermined percentage) will also have fish and salmon, the distribution data should be useful in generally identifying where fish in streams may be affected by additional mining activity. This report was obviously preliminary work by the authors, and the importance of the issue suggests that a much more extensive study might be called for and would clarify more precisely distributions and perhaps relative abundance of resident and anadromous fish within the basins potentially affected.

The numerous limitations described above for this paper are much more serious in some kinds of studies than others. In many studies with some very rigorous, complex objectives, in need of very careful testing and evaluation, problems as observed in this paper can be fatal to the credibility of the study. In other studies, where the objectives are more modest, the limitations identified are less crucial and more of an annoyance. Compared to most studies, fish presence/absence studies are more straightforward, and limitations as identified above do not necessarily invalidate the main scientific conclusion regarding presence/absence.

Fundamentally, the authors concluded that in a high fraction of the streams within the proposed area, certainly the lower gradient streams that they evaluated, nearly all of them had fish and nearly 75% of them had salmon. The conclusions are best presented in the Appendix figures. That conclusion is scientifically supported in this work, even with the limitations on the study design and with the shortcomings of how the work is presented. For that reason, I do not see the limitations of this study as invalidating the above conclusion, and the paper would, in my professional opinion, be a suitable scientific reference in that limited context.

William J. Wilson

In general, since this is a report that documents fish and habitat surveys conducted in several headwater streams of the river drainages that may experience impacts from the proposed Pebble Mine activity, it relates to the EPA assessment in that it documents additional habitat for anadromous fish not previously included in the Catalog. Since the Catalog is the authoritative reference for Title 16 permitting, inclusion of streams likely to be impacted by development will improve future environmental assessment of a specific mine development scenario and will help regulators condition future permits granted if this project proceeds. However, the report does not provide the quantitative data needed to characterize the relative importance of the areas surveyed to the overall production of fish in the Nushagak and Kvichak River systems, and in turn, to fish production in the larger Bristol Bay watershed. Lack of specific information on species collected in sites/reaches that are within the mine footprint, or downstream of presumed development sites, limits the application of this report's results to the EPA assessment. Furthermore, the locations of the streams surveyed relative to the proposed mine itself are not well shown in the report, but I presume they are well known to EPA and I also presume were included in the draft EPA assessment. But to me as a reviewer, I can only judge what is provided in the report and not second-guess what supporting data and information not included in the report were made available to the EPA assessment.

III. PEER REVIEW OF WOODY AND HIGMAN 2011 REPORT

III.1 Charge Questions

1. Are the conclusions of the report well-supported by the evidence provided? Why or why not?

2. What are the strengths and weaknesses of the Woody and Higman 2011 report, in terms of:

    a. Methodology?

    b. Results and conclusions?

3. Are there important limitations or uncertainties associated with applying results from the Woody and Higman 2011 report to the EPA assessment? If so, what are they?

III.2 General Impressions

Michael R. Donaldson

Woody and Higman 2011 provide a report on groundwater as essential habitat for salmon in the headwaters of the Nushagak and Kvichak River watersheds, which produce a large proportion of Bristol Bay salmon. The report addresses three objectives: (1) summarize and review relevant groundwater ecology principles; (2) document salmon and groundwater interactions; and (3) summarize potential risks to groundwater quantity and quality posed by proposed large-scale mining operations in the region. For objectives 1 and 2, the literature review appears to be well-referenced and accurate, albeit brief. Objective 3 lists the most prevalent risks in rather cursory detail and does not describe potential additional risks (suggested below). The report is well-written and concise, covering the essential information in a manner which can be understood by readers of different backgrounds and expertise. The tables and figures are well-described and appropriate. The conclusions state that groundwater represents essential salmon habitat, which is a sound conclusion based on both the content of the report and the well documented value of groundwater to salmon that can be found in the broader literature. The conclusions re-state the risks of mining operations on groundwater quantity and quality, risks that could potentially cause irreversible damage to the habitat and ecosystems in the region, including potential declines in salmon productivity – a conclusion which is certainly sound - but could have benefitted from being related to past examples of groundwater contamination due to similar mining operations.

James M. Helfield

This report contains a well-researched and clearly-presented review of the current literature regarding the importance of subsurface exchange (i.e., groundwater and hyporheic upwellings and downwellings) to spawning and rearing habitat for Pacific salmon. The report makes convincing use of the peer-reviewed scientific literature to demonstrate that subsurface exchange is crucial for the diversity and long-term viability of salmon populations in Alaska. This report also provides compelling evidence that subsurface exchange is prevalent and important specifically within the Pebble prospect, and that mining activities are likely to affect both the quantity and quality of subsurface waters, resulting in potentially significant impairment of salmon habitat.

Dennis L. Scarnecchia

This paper is best characterized as an overview paper, with some characteristics of a review paper, presenting a range of plausible concerns about how changes in groundwater quality associated with the potential mining activity may affect spawning and other habitat for native salmonids. It uses scientific literature from other studies in an appropriately qualified way. With one exception, it does not arrive at any specific conclusions; it only says that, based on the available literature, there is potential for impacts. The exception is on page 11 regarding outcomes of the Prospect (the paragraph starting with "Multiple pathways"...). This paragraph makes some fairly specific predictions, as opposed to the rest of the paper, which is only discussing plausible relationships. The level of prediction here is beyond that of the rest of the paper, and, although plausible, seems to go beyond the conclusions possible from this general

overview.

The only new scientific information presented that is not from previously written work is the relationship between open water areas, ostensibly indicative of upwelling groundwater, and presence of salmon spawning habitat. It has no components of a laboratory study on groundwater and salmonids (e.g., Webster and Eiriksdottir 1977. Trans. Amer. Fish. Soc. 105:416-421) nor does it have any field component with measured groundwater to verify assumptions about groundwater and open water (e.g., Baxter et al. 2003. Trans. Amer. Fish. Soc. 132:493-502.). It would be necessary to more specifically verify this connection in a future study. The rest of the paper is a review of scientific literature relevant to presenting plausible areas of concern. Overall, the use of the fisheries literature appeared appropriate in terms of presenting possible concerns, but not necessarily specific outcomes. The third objective of the paper was to identify *potential risks* and it does that. With the one exception above, it qualifies its concerns appropriately with words such as "potential," "can," and "may," recognizing that more detailed studies are clearly needed. The paper is not very well organized and would have benefitted from more peer review.

William J. Wilson

This report describes observations made during a one-day (March 11, 2011) survey of streams in the headwaters of the Nushagak and Kvichak Rivers in the Bristol Bay region, Alaska. This survey identified areas of open water on ice-covered streams as evidence of potential warmer groundwater upwelling and, in turn, potentially good fish (salmon) habitat. The report provides a good review of literature on the relationships between groundwater and surface water flow in small stream systems and the possible ecological benefits of groundwater upwelling to fish. The field observations presented in this report appear to be sound and relevant to understanding the importance of winter water conditions to fish in these small upper-drainage waters. The conclusions in this report, however, are not supported by the information provided. This report strays from the purpose as outlined in the title to a series of hypothetical and often random statements about mining impacts, concluding that a specific development, the Pebble Prospect, has the potential to "significantly impact" fish without providing in this report data or information on the mine development plan, locations of specific mine facilities, mitigation measures to be employed, and many other unknowns. This report should have focused primarily on describing the nature of this field trip, the information obtained, and how this information might be relevant to mine development assessments; instead the report presented, on the last page of the narrative, considerable detail on acid drainage from mines, and metal toxicity, including particularly copper effects on fish physiology.

III.3 Response to Charge Questions

Question 1. Are the conclusions of the report well-supported by the evidence provided? Why or why not?

Michael R. Donaldson

The conclusions relating to objectives 1 and 2 state that groundwater is essential salmon habitat. This conclusion is well-supported by the evidence provided in the report, the literature cited, and is also supported by the broader literature as well. The report summarizes how groundwater quality and quantity influences salmon throughout various lifestages and is an integral part of their productivity. The conclusion relating to objective 3 regarding the risks associated with mining operations to groundwater quantity and quality are also well-supported by the evidence provided since the authors discuss how mining operations could influence both quantity (e.g., due to dewatering) and quality (e.g., due to contamination from tailings ponds or other mining operations). The conclusion for objective 3 would have benefited from the authors providing examples of scenarios where similar mining procedures where groundwater quality and quantity has been affected and the resulting effects of nearby ecosystems and fish populations. Additional confounding factors, such as extreme weather events leading to flooding, landslides, and heavy snowpack were not discussed likely because they fall beyond the scope of the report, but could lead to increased risk to groundwater. Even so, the authors present sufficient information for the conclusion relating to objective 3 to be justified. While some details are communicated rather generally in favor of brevity, the conclusions are clearly articulated and appear to be justified given the content and scope of the report.

James M. Helfield

The conclusions of the report are well supported by the evidence provided. Regarding both the importance of subsurface exchange to salmon habitat and the potential effects of mining activities on the quantity and quality of subsurface waters, the literature cited is current, relevant, and from credible, peer-reviewed sources. All of the report's conclusions follow logically from the evidence provided.

Dennis L. Scarnecchia

The conclusion (page 11) is that "mining… has the potential to significantly impact salmon productivity, biodiversity, and sustainability through loss of habitat and water contamination." That qualified conclusion is supported adequately. The use of literature documenting potential effects to salmon is appropriate. No specific outcomes are predicted, with the exception of some comments on page 11 regarding Prospect outcomes (the paragraph starting with "Multiple pathways….."). Although the conclusions on the Prospect are not listed in the conclusions section, some specific outcomes are listed here that are not fully defended based on more general content of the paper.

William J. Wilson

The conclusions of the report are not well supported by the data collected during the field trip described in the report. The field trip was conducted to document open water conditions in streams of the upper Nushagak and Kvichak River drainages. Open water could be an indicator of groundwater upwelling, which has been documented to be an important physical factor influencing fish spawning locations and successful fish embryonic development in stream substrates. Upwelling also may provide important winter habitat features for juvenile fish that inhabit interstitial areas among coarser substrates. This report was to have reported on this field effort, and then describe how the observations made during that field effort relate to evaluating issues relative to mining. While the report presents some water quality issues associated with mining that explore how groundwater may present opportunities for exchange of water from the mine area and streams that may harbor fish, it does so via a series of hypothetical statements about the proposed mine development without including a detailed development plan that describes how the ore body will be penetrated and extracted. It seems premature to make such statements in the conclusion of the report (page 11) without background information on the mine development plan.

Question 2. What are the strengths and weaknesses of the Woody and Higman 2011 report, in terms of:
a. Methodology?
b. Results and conclusions?

Michael R. Donaldson

a. Methodology?

The background and context information is a strength. The authors provide a concise yet thorough overview of the relevant literature and communicate it effectively.

The methodology for detecting groundwater presence represents a weakness in my opinion. The authors relied on visual assessments of open water during March 2011 to indicate groundwater presence. Open water could be influenced by a number of factors including temperature changes (reported temperatures fluctuated ~10 °C during the study period, reaching temperatures > 11°C), which could influence the amount of open water. River flows of surface water (or combined surface/groundwater) along steep gradients or river constrictions alone could influence open water as well. So, open water areas may not always be indicative of groundwater upwellings. Conversely, areas that are frozen over could still represent locations where groundwater inputs occur (e.g., pack ice accumulation in certain locations or even snow cover could mask locations where groundwater upwellings occur, particularly when viewed from the air. Insufficient information on the methods are included in the report to know whether or not these concerns are valid. As such, the methods used for assessing groundwater presence may not be very accurate depending on environmental conditions at the time of the study. Regardless, the literature review clearly points to the value (i.e., the necessity) of groundwater inputs for salmon habitat, so even if the methods are not entirely accurate and quantitative, it should be assumed that groundwater is certainly a critical component of salmon habitat in this region, as is the hyporheic zone.

b. Results and conclusions?

The paragraph above summarizes some potential concerns with the accuracy of determining groundwater presence. Depending on environmental conditions, groundwater input could either be over- or under-estimated by that method. The results reflect this uncertainty as Figure 5 contains the only true data, which is an overlay of open-water areas on salmon habitat throughout the region. The figure provides a nice first step, but it appears as though more data are required in order to develop a more quantitative relationship between groundwater input and salmon habitat. Even though the data were not presented in a quantitative manner, this information is important and certainly provides evidence of groundwater input in spawning habitats. However, I think revised methods and additional data collection should be considered in order to arrive at a more accurate determination of groundwater upwellings throughout the region.

Regardless of the limitations described above in relation to estimating groundwater upwellings, the conclusions remain justified given the stated objectives and content of the report.

James M. Helfield

a. Methodology?

The main strength of the report's methodology lies in its compelling and comprehensive use of credible and current scientific literature. The report's only substantive weakness lies in the methods used to document groundwater upwelling in the headwaters of the Nushagak and Kvichak drainages, as described in Appendix I. The assumption that open water in March is a strong indicator of groundwater upwelling is likely valid, but a more definitive approach would be to measure upwellings directly using piezometers and tracers or measurements of spatial patterns of temperature, dissolved oxygen, and solute concentrations. Such direct measurements would provide better support for the report's conclusion that upwellings are ubiquitous in state mine leases. These findings are bolstered to some extent by the fact that they corroborate those of previous studies (i.e., Florio 2007, Cathcart 2008, Smith and McCreadie 2008), but the methods used in those previous studies are not described, and it is not clear if they were peer-reviewed.

b. Results and conclusions?

The conclusions drawn in this report are well supported by the evidence presented. The only conclusions that could be better supported are those pertaining to the ubiquity of groundwater upwellings within state mine leases (see comment above), but even these conclusions corroborate those of previous studies and are based on assumptions that are likely valid.

Dennis L. Scarnecchia

a. Methodology?

The paper is mostly a review paper, drawing attention to possible relationships in need of more detailed evaluation. It is not a field study or a lab study, and not very methodological. The most critical methodology that is not analyzed in any detailed way is the assumed linkage between open water areas and presence of groundwater. The authors provide some evidence in support of this assertion in terms of air temperature data, and it is clearly plausible that there is a relationship between open water areas and presence of groundwater. However, open water as opposed to frozen over can also be associated with factors, such as river gradient and velocities. It would have been very useful if even a small study had been designed to measure or identify groundwater sources in those open water areas as opposed to their absence in areas frozen over. This would have taken longer than the duration of this study, however. It should be done in any follow-up studies. On Page 9, the authors refer to "unreleased results" documenting ubiquity of upwelling groundwater and the linkage between open water and groundwater. This sentence was difficult to understand. If the results were unreleased, why were they referenced at the end of the sentence? Or is there other information that has not been released?

b. Results and conclusions?

The discussion of how salmon benefit in general from groundwater by season (spawning, overwintering, etc.; pages 5-6) is accurate.

William J. Wilson

a. Methodology?

This report provides a good review of literature on the relationships between groundwater and surface water in small streams, and the potential ecological benefits of groundwater upwelling and the hyporheic zone. Groundwater upwelling areas may provide fish habitat, and the report describes well some of the literature developed on relationships between groundwater upwelling and fish habitat. The report's title suggests it will explore issues associated with groundwater/stream water interactions and the hyporheic zone, which it does in very general terms. Additional literature review, and a much more extensive field effort, would be required to more clearly and quantitatively define the relationships between groundwater and fish habitat in the proposed mine development area. A notable weakness of the methodology is the very limited field study – one day. Some mapped locations of open water areas along the course of ice-covered streams may indicate upwelling, and perhaps fish habitat, but without a confirming study of fish presence in those areas, and surveys on additional days and additional geographic areas, this report has limited application. Furthermore, the report states that 175 miles of open or partially-open water was documented "in both rivers and smaller headwater streams"; since a concern of this report is potential mine impacts on small headwater streams, what proportion of the field survey effort was on these small drainage streams versus "rivers?"

b. Results and conclusions?

The general results of the field study are well documented. However, the total length of streams surveyed is not provided; the text reports only "open or partially open water" (175 miles); since this study was accomplished in winter, presumably some portions of these streams were ice covered. What proportion of the total ice-covered streams surveyed contained open or partially-open water? Of most concern is the unsupported conclusion of the report that is discussed above under "General Impressions." Other weaknesses/editorial concerns for this report are provided below.

Additional Comments

- The Rationale of this report cites State of Alaska information that document sport fishing expenditures in Southcentral Alaska alone are nearly one billion dollars annually; perhaps this is true, but reporting this large a sum might merit confirmation.
- This report uses the term "State mine leases" without putting into context the proposed Pebble development's aerial extent of actual ore body development. What proportion of the total area leased would be the Pebble Prospect, and what proportion of that area would be the land area impacted by ore removal? This would help put into context the overall aerial extent of potential stream disruption.

- In the description of the hyporheic zone, the authors suggest salmon may move through wetted underground alluvium to access adjacent stream areas; additional referencing would help justify this statement, including specific methodology used to document such fish movement.
- The georeferenced stream segment in Photograph C apparently illustrates where 25 cfs groundwater flow moves from one drainage system into another; when did this occur (winter?) and how was this measured?
- Craven et al. *In Review* is cited on page 10 but not included in the literature cited; even if this report is only in review, its title should have been footnoted or included in the Literature Cited section.
- The very detailed descriptions of side channels, tailings sites, springs, hills, tailings storage facilities, etc., in the Pebble Prospect on page 11 are too specific and are extraneous detail that were not part of the field study nor the literature review.
- The next-to-last sentence in the report discusses how development of high acid mines poses a high risk for exceeding water quality standards; which State's standards? Alaska's? Mine development, and specifically the levels of acid in mine discharges, were not the subject of this report; this statement seems out of place.

Question 3. Are there important limitations or uncertainties associated with applying results from the Woody and Higman 2011 report to the EPA assessment? If so, what are they?

Michael R. Donaldson

The report accurately describes the value of groundwater to salmon by assembling relevant information from the literature. However, the report also adds new data in attempt to link groundwater upwellings with salmon habitat – while these data could potentially be valuable, they are not described in sufficient detail in the report to be useful on their own. Below I discuss two ways of collecting additional data that could help to reduce the uncertainty here and make this information more valuable to the EPA assessment. It should be noted that despite these limitations, this report remains a valuable resource for describing groundwater-salmon interactions and associated risks to groundwater quantity and quality in relation to mining operations.

i) One knowledge gap that apparently remains is a thorough and quantitative assessment of the groundwater table, including groundwater upwellings in salmon habitat for the entire region of the proposed mine. The methods described in this report, along with the fact that few results and little interpretation were incorporated here, suggest that additional large-scale studies are required before a full assessment can be made.

ii) Another knowledge gap is that the report mentions that there remain many tributaries in the region of the proposed mine where fish surveys have not yet taken place (or at least few data exist) suggesting that there may be important additional spawning or rearing habitat that has not yet been fully described. A thorough assessment of potential spawning areas in tributaries would be extremely valuable, and ideally should be done over a multi-year period to enable enumeration or at least estimations of the number of out-migrating salmon in these potentially vulnerable areas.

iii) Combining both comments (i) on assessing groundwater input and (ii) on assessing the scale of salmonid spawning habitat is highly relevant for the EPA assessment. Given the importance of groundwater for salmon (as indicated in this report), knowing the extent of groundwater input, mixing of groundwater and surface water (e.g., a better characterization of the hyporheic zone), and the extent of the groundwater table in relation to salmon spawning habitat is critical when discussing a mine of this scale. Figure 5 provides an excellent visualization and a great first step to linking groundwater upwelling with salmon habitat, however, the data collected remain on a very rough scale and it is apparent that some data are missing since there may be additional spawning areas which have not been included. Although this qualitative information is excellent, some refinement is needed in order to arrive at a quantitative assessment of the extent of groundwater upwellings and their locations in relation to spawning habitats (including the poorly documented tributary areas). As such, filling the knowledge gaps of (i) and (ii) and linking them together to better identify how they interact should be a top priority. This report is a great start towards linking these concerns, but more quantitative data collection is required in order to gain a better understanding of their interactions, which should be a priority of the EPA assessment.

James M. Helfield

I see no important limitations or uncertainties associated with applying results from this report to the EPA assessment.

Dennis L. Scarnecchia

Because of the very preliminary approach taken in this paper to assessing potential groundwater effects of mining and salmon, this paper should not be viewed as a substitute for more thoroughly designed studies to assess more specific aspects of the groundwater and salmon linkage. One positive value of the paper is that it outlines several areas within those basins where more detailed field studies are needed. Overall, the science in the paper regarding salmon is used appropriately, but little specific field information is available to predict specific outcomes. Several of the geology-groundwater-salmon linkages identified in this paper need to be understood more fully, and this information is important in evaluating whether or not significant impacts will occur.

William J. Wilson

I believe this report is relevant to the EPA assessment in that it provides some general information on groundwater/stream water interactions in Alaskan streams. This relationship has relevance to salmon spawning and fish rearing, and may be important information that will lead to further field studies of this nature. Only a single field trip is described, and that effort was a single day in the field completing aerial surveys of over 175 miles (or more?). The study has limited application to impact assessment since it does not document actual fish presence in areas identified as open water and potential fish habitat. Additional field studies could be conducted to examine relationships between stream water and groundwater upwelling, including additional field trips during other seasons of the year and in other areas of the potentially-affected watershed, piezometer studies of groundwater elevations relative to adjacent stream water surface elevations, dye studies of water exchange, and perhaps incubation studies of fertilized salmon eggs placed in the area's streambed gravels to study stream and groundwater temperature regimes as they relate to successful embryonic development and hatching (success, timing). Since this report also delves into metals toxicity and implies that mining may contribute contaminants to groundwater systems that exchange with fish-bearing streams, further field examination of these linkages would be warranted as described above. Overall, this study is interesting and relevant, but limited in scope and too general in nature to contribute to quantitative assessment of development impacts.