Report To The University Of Miami Independent System For Peer Review

Salmon Matrix Review

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12th January 2001

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1. EXECUTIVE SUMMARY

1.1 This review involved consideration of the aquatic matrix developed by federal and state authorities for the Pacific Lumber Company Habitat Conservation Plan (HCP). The matrix puts forth a condition for the landscape which has been determined to be "properly functioning" in order to meet the needs of anadromous salmonids and other aquatic species on Pacific Lumber Company properties in Humboldt County, Northern California. Specifically, the review sought to address the suitability of the metrics proposed in the matrix and the values assigned to them. Reviewers were also invited to propose alternative metrics and values where deemed appropriate. In addition, the review sought identification of the most appropriate metrics for the assessment, monitoring and adaptive management of aquatic candidate salmonids in this region. Finally, the efficacy of functional and practical linkage of instream and riparian metrics with upstream watershed processes were to be assessed.

1.2 The matrix proposes a series of "pathways" and "indicators" of habitat conditions with specific narrative and/or quantitative targets. This represents a valuable first step in identifying some of the key environmental variables influencing the habitat of threatened and candidate salmonids, and using them as a basis for the adaptive management of land use practices in watersheds.

1.3 However, in its current form the matrix is unlikely to provide adequate protection for these species for the following reasons.

- Although in general the metrics that are used are relevant to the habitat requirements of salmonids, the interdependent nature of many of the indicators identified are not considered in an integrated manner by the Matrix. This lack of integration is poorly matched to the functional ecology of aquatic systems and is therefore likely to be too simplistic to provide a basis for habitat protection.

- The matrix does not adequately consider the marked natural spatial and temporal variation in habitat conditions within and between salmon producing watersheds. Thus ranges or distributions of metric vales would be more appropriate than the single values that tend to be given.

- The values of metrics within the Matrix are not well related to the level of risk to salmonid populations in different watersheds resulting from the impact of forestry activities on habitat indicators, as both risk and impacts will vary in both space and time.

- In addition, the values of the metrics used in the Matrix are not always appropriate. In some cases they are based on data from areas outwith the redwood region, more seriously the spatial and temporal scales to which they refer are often not specified.

- It is unclear how the Watershed Analysis, which is implicit in the implementation of the Matrix, will link in-stream and riparian habitat conditions with watershed-scale processes in a manner that will allow adaptive

management to occur. As it stands, it is not at all apparent how the feedback loops will help modify management as the understanding of habitat conditions in a particular watershed progresses and forest management plans evolve.

- There is an urgent need to collect more data on the biotic target species in different watersheds to establish empirical relationships between salmon populations and habitat conditions.

- Without such information it is extremely unlikely that the consequences of the cumulative impacts of watershed management can be identified and addressed.

1.4 Given these limitations, it is essential that the Matrix is developed further and its links with the Watershed Analysis protocols are considered more fully to provide a mechanism with the potential for integrating habitat targets for salmonids with the characteristics and management plans for particular drainage basins. This analysis needs to combine broad scale GIS analysis with more detailed field surveys to develop a conceptual model of watershed functioning and provide a basis for defining and achieving realistic habitat targets which link to the needs of salmonid populations. This should include an assessment of salmonid populations within the watershed and attempt to understand cumulative impacts in the context of the biological response. A framework is also needed whereby monitoring of these habitat indicators can inform management decisions to provide adaptive management that will influence Timber Harvesting Plans (THPs).

1.5 Monitoring habitat conditions in streams will contribute little to the goal of salmonid protection unless watershed processes, and in particular hillslope - channel linkages, are managed in an integrated manner. The Watershed Analysis provides a framework for this, but as it stands the HCP gives inadequate protection to riparian zones, particularly those fringing Class III channels which constitute major source areas of storm runoff, sediment and woody debris. Conservative approaches to buffer strip protection are essential if risks to salmonid habitats resulting from forestry operations are to be minimised.

1.6 The result of more comprehensive analysis may have the consequence of large areas of watersheds being unavailable for timber harvests, which it is recognised is likely to create politically and economically difficulties. However, such an approach may well be needed if the protection of endangered and candidate salmonids in northern California is to be a serious management objective.

2. BACKGROUND

Terms of reference

2.1 This review involved consideration of the aquatic matrix (referred to hereafter as "the Matrix") developed by federal and state authorities for the Pacific Lumber Company Habitat Conservation Plan (HCP). The Matrix puts forth a condition for the landscape which has been determined to be "properly functioning" in order to meet the needs of anadromous salmonids and other aquatic species on Pacific Lumber Company properties in Humboldt County, Northern California.

2.2 The original terms of reference for the review were set out by The University of Miami System for Independent Review Statement of Work (SOW) as detailed in Appendix A. Essentially reviewers were tasked to address four questions:

1. Are the metrics used in the matrix appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species? If not, which metrics would be appropriate and at what landscape scales?

2. Are the values provided for the metrics appropriate for assessing aquatic and associated riparian habitat condition to meet the needs of threatened and candidate salmonid species in coastal redwood systems? If not, which values would be appropriate and at what landscape scales?

3. Which metrics are the most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate salmonid species in coastal redwood systems?

4. How should in-stream and riparian metrics be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression?

2.2 These were subsequently clarified by the Addendum to the Statement of Work shown in Appendix B which emphasizes the following:

1. In question 3 on the Statement of Work, reviewers are asked to consider which metrics are most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate salmonid species in coastal redwood systems. The reviewers are to incorporate their findings from question 1, which asks whether the metrics used in the matrix are appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species, and if not, then which metrics would be appropriate and at what landscape scale. These findings from question 1 may provide a subset of metrics that are appropriate for the specific habitats in coastal redwood systems. If there are other metrics that are more appropriate and not used in the matrix, the reviewers may address these as well.

2. In addition to question 4 on the Statement of Work, the following question may assist the reviewers on addressing the applicability of the matrix framework:

   Does the matrix framework provide adequate tools and guidelines for stream and riparian metrics to be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression? If not, what additional features, properties, or guidelines should be addressed to the matrix framework?

Panel membership

2.3 The review was undertaken by an interdisciplinary panel with the following five members.

Dr Mike Bradford, Fisheries Scientist, Department of Fisheries and Ocean, Vancouver, Canada.

Professor Rick Cunjack, Fisheries Scientist, University of New Brunswick, Fredricton, New Brunswick, Canada.

Dr Larry Marshall, Fisheries Scientist, Department of Fisheries and Ocean, Dartmouth, Canada.

Professor Richard Marston, Fluvial geomorphologist, Oklahoma State University, Stillwater, Oklahoma, USA

Professor Chris Soulsby, Hydrologist, University of Aberdeen, Aberdeen, Scotland

Date, location and schedule of review activities

2.4 The review meeting was held in Arcata, California between 27 and 30 November 2000. Prior to the meeting the review panel had been sent three volumes of documents relevant to the Matrix, which are detailed in Appendix C. The review meeting was hosted by the National Marine Fisheries Service (NMFS) and co-ordinated by John P. Clancy.

2.5 In addition to the literature circulated, the panel was provided with a list of relevant contacts in the Arcata area who might provide further information relevant to the review. These are listed in Appendix D.

2.6 The review meeting comprised the following activities, some of which were pre-arranged, others (such as meetings with particular individuals) were set up at the request of the review group or individual group members.

27th November:

Initial briefing: Involving the review panel and NMFS staff.
Presentations: Detailed in Appendix E.

28th November:

Field visit to old growth redwood streams at Prairie Creek (led by Randy Kline of the Redwood National Park).

29th November:

Meetings: with Margaret Tauzer (NMFS) , Maryann Madej (USGS) and S Sharon Kramer (Stillwater Sciences)
Visit to logged areas in the lower and South Fork Elk basin (led by John P. Clancy).

30th November:

Field visit to Simpson Timber Company property to inspect sediment control management on forest roads (Led by Mathew House, Simpson Timber Company).

Meeting: with Leslie Reid (PSW Redwood Sciences Laboratory).
Meeting of review group.
Meeting: with Sam Flanagan (NMFS) and Danny Hagan (Pacific Watershed Associates)

2.7 Since the review meeting, additional material (listed in Appendix F) has been consulted as part of the synthesis of the review and writing up of the current report.

3. **MAIN FINDINGS**

<u>Specific responses to questions in the Statement of Work</u>

1. *Are the metrics used in the matrix appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species in coastal redwood systems? If not which metrics would be appropriate and at what landscape scales?*

3.1 Before considering the merits or otherwise of the particular metrics used, it is important to establish some important generic principles regarding the concept of a "properly functioning" aquatic habitat condition that the Matrix seeks to achieve in order to protect threatened and candidate salmonids. Whilst the relatively straight forward list of habitat indicators (with targets) which the Matrix provides has clear attractions from a managerial perspective, it is a methodology which has major difficulties when attempting to apply it to complex, interactive ecological systems. The specific metrics cited in the Matrix are considered in more detail in response to the second question in the SOW, however the following issues are relevant to virtually all of the indicators listed.

3.2 In a general sense, many of the metrics proposed in terms of pathways and indicators are measures of environmental variables known to be important for salmonids. However in the Matrix they are generally considered as isolated variables with narrative or numeric targets that current and future habitat conditions can be measured against. The preamble to the Matrix explicitly recognises, "all indicators are interrelated, many are interdependent, and should be viewed together as a functioning system". Such functional linkages between these environmental variables are usually imperfectly understood in aquatic systems, and thus it is not surprising that there is no clear indication of how this synergy will be incorporated in application of the Matrix. This lack of integration in the consideration of habitat metrics within the Matrix is a major flaw, which ultimately undermines confidence in the ability of the methodology to deliver a "properly functioning" aquatic habitat.

3.3 A second major philosophical concern regarding the notion of metrics with numeric target values is that habitat variables, even in aquatic systems of undisturbed watersheds, vary spatially and temporally. The spatial variation can reflect natural differences in watershed characteristics (climate, soils, geology etc.), whilst temporal variability, particularly in a geomorphologically active area such as northern California, may be manifest in a number of ways: on short time scales (i.e. daily) water quality variables such as turbidity may vary dramatically as rainfall events increase flows; over longer timescales, larger disturbances can occur, for example in more extreme rainfall events (i.e. > 10 years) or following tectonic episodes (i.e. > 100 years) which can affect major geomorphic change in watersheds and river channels. Thus the concept of the Matrix and a set of "idealised" static habitat targets sits uneasily with the reality of dynamism and variability exhibited by the types of aquatic systems which salmonid species are adapted to.

3.4 Related to this lack of spatial and temporal discrimination, the Matrix is not closely allied to the concept of risk. In this context, risk relates to the potential adverse impact of forestry operations on habitat variables that are likely to influence

candidate and endangered salmonids. The spatial and temporal variation alluded to in paragraph 3.3 above dictates that the vulnerability or risk of damage to salmonids in particular watersheds resulting from forestry operations will vary in space and time. Moreover, forest practices themselves will also alter the risk of further damage by, for example, increasing the probability of hillslope mass movements or altering watershed hydrological routing (Sidle *et al.*, 1991). Although there are implicit links between use of the Matrix, Watershed Analysis and the subsequent production of Timber Harvesting Plans (THP) in the Habitat Conservation Plan (HCP), there is little evidence of how knowledge of changing risk scenarios will be applied in adaptive management of watersheds. This lack of a clear management feedback loop is inconsistent with the usual characteristics of adaptive management.

3.5 A further key conceptual difficulty with the matrix is that there is often an absence of a clear, explicit statement of what spatial and temporal scales are being considered for the assessment of individual habitat variables. Clearly the Watershed Analysis procedure, which is an integral part of the HCP and implementation of the Matrix, provides the potential to frame the scale of particular management objectives explicitly. However the linkages between the assessment of habitat indicators cited in the Matrix and the Watershed Analysis are simply not clear. Although the Watershed Analysis is focusing on meso-scale (10,000 – 50,000 acre) basins, there is no explicit statement of a nested hierarchy (eg. Watershed, sub-basin, channel reach, channel unit etc) for monitoring habitat variables over different timescales as a basis for appropriate adaptive management. As watershed monitoring should always be clear about the spatial and temporal scales over which variables are being measured (see Madej, 1999a), this appears to be a further serious methodological impediment to the Matrix achieving its objectives.

3.6 The focus of the Matrix is on habitat conditions which are assumed will provide a suitable environment for threatened and candidate salmonids. However, evidence collected during the Review Meeting indicated that relatively little empirical data is available on the size, structure, composition and distribution of salmonid stocks in the rivers of northern California. Consequently, information on the functional linkages between indicators in the Matrix and biological targets is scare and the lack of empirical relationships dictate that these linkages are therefore usually implied (or assumed). Thus, the differences between fish populations and habitat conditions in undisturbed watersheds and those which have been impacted to different levels, appear to be poorly understood (Nakamoto, 1994). This again leaves one uncertain as to how the collection of data on the indicators listed in the Matrix can be linked in a meaningful way to the different watersheds covered by the HCP. Again, this offers little support to the utility of the Matrix, as it stands, as a tool in the protection of salmonid populations.

3.7 Biological “target species” in aquatic systems are affected by the complex interaction of a multiplicity of contemporary and historic environmental factors and pressures, which can in turn be affected differentially by a wide range of future activities. The notion of “cumulative effects” has clearly been considered in some depth by scientists and managers working in the redwood region (Reid, 1998; Science Review Panel, 1999). In many cases such “cumulative effects” are difficult to identify without comprehensive Watershed Analysis. In addition, the identification of appropriate thresholds of controlling variables beyond which undesirable impacts may

result from particular processes is equally difficult. This is an important issue as watersheds with differing degrees of cumulative impacts will all have different baseline habitat conditions and contrasting potential for habitat improvements. Clearly there are advantages in prioritising and maximising efforts in those basins with the best medium – long-term prospects for the protection and enhancement of endangered salmonids. Moreover, identification of legacy issues, such as major sediment problems in high priority salmonid producing watersheds, provides a basis for rapidly focusing on mitigation measures.

3.8 In some cases the metrics (and values quoted) are based upon measurements and studies outwith the redwood region. Whilst in many cases, studies are drawn from the Pacific north west region in general, work from the redwood region itself highlights many unique characteristics of habitat conditions that presumably salmonid populations are well-adapted to (Welsh *et al.,* 2000). In particular, recent published work from the Redwood region provides an insight into metrics which are perhaps more appropriate for the area which forms part of the HCP (Nolan *et al.*, 1995; Prager *et al*., 1999; Ziemer, 1998a; Taylor, 1999). At present there appears to be no mechanism for utilizing the results of new and future scientific studies to improve the metrics used in the Matrix.

3.9 It could be argued that the large number of indicators result in a relatively complex matrix. The metrics used for different indicators are highly varied from very prescriptive numeric targets (eg fine sediments etc.) to very vague narrative statements (eg impacts on peak flows and baseflows). In other cases the metrics are awaiting development reflecting the nature of the Matrix as a "work in progress". In some places, one gets the impression that the precision of indicator values often reflects the availability of well-established protocols which render the measurement of a particular metric relatively easily. There are two extreme interpretations of this unevenness of metrics, lack of integration, non-specific reference of spatial and temporal scale, and absence of empirical data on biological targets, on the utility of the Matrix: A positive interpretation would be that the metrics used in the Matrix still provide a useful starting point which, through a series of iterations, could provide a useful tool for evaluating baseline habitat conditions for salmonids in the basins covered by the HCP. A more pessimistic interpretation could be that the Matrix gives an illusory veneer of scientific credibility to a fundamentally flawed management approach.

2. *Are the values provided for the metrics appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs of threatened and candidate salmonid species in coastal redwood systems? If not, which values would be appropriate and at what landscape scales?*

3.10 Some observations on the values for the metrics used are listed in the following section. Many of the limitations with the values listed relate to the conceptual problems of the Matrix highlighted in the preceding response to the first question in the SOW. Consequently, the emphasis in this section is not so much the identification of new metrics with "magic" numbers for habitat indicators which will guarantee the protection of candidate and endangered salmonids. This would be unrealistic. Rather, the emphasis highlights some of the limitations of the current metrics (and their

values) for impact pathway indicators, and provides some suggestions as to how the concepts of the Matrix can be recast in a management framework that is more in line with the aim of providing habitat conditions to meet the needs of salmonids.

3.11 To achieve this involves developing an approach that recognises the interrelationships between habitat variables in watershed systems, has a clear scale-specific context (in both time and space), focuses on feasible value ranges for habitat variables and is capable of being used in an adaptive management paradigm. Many of the comments that follow are consistent with the research of the numerous watershed scientists working in the Pacific north-west. Although published after the latest version of the Matrix was produced, the Proceedings of the "Conference on Coastal Watersheds" (Ziemer, 1998a) are particularly relevant, as are those of the workshop on "Using stream geomorphic characteristics as a long-term monitoring tool to assess watershed function" at Humboldt State University (Taylor, 1999). In addition, the considerations of the Science Review Panel (1999) of the California Forest Practice Rules highlights many of the difficulties associated with some of the concepts embedded in the Matrix.

Water quality

3.12 The 11-8 – 14.6 ^{o}C Maximum Weekly Average Temperature (MWAT) targets are based on theoretical considerations outlined in attachment "A" of the Matrix. Whilst temperature is undoubtedly a key factor governing fish dynamics in stream systems such a target metric is a fairly blunt management tool. Temperature shows natural variability in watersheds in relation to factors such as receipt of solar insolation (governed by aspect, shading etc), groundwater discharge etc. and thus it would be more appropriate to have empirically based target ranges for particular watersheds. For example, different prevailing conditions in watersheds already differentially impacted by logging would result in contrasting targets being appropriate. Moreover, with improved data collection these values could better reflect the impact of temperatures on the bioenergetics of particular streams. The arguments against the use of the kinds of metrics and values quoted are well-rehearsed by others, such as the Scientific Review Panel (1999), who concluded that such metrics are conjecture in the absence of site specific analysis of habitat and fish conditions.

3.13 The critical factor in managing sediment problems in watersheds is preventing increased sediment delivery at source, rather than dealing with the symptoms. Thus it is difficult to follow the logic of prescribing a series of metrics for sedimentary indicators prior to dealing with hillslope sediment delivery mechanisms as cited within the Matrix. Clearly, the links between the Watershed Analysis, identification of Mass Wasting Areas of Concern (MWAC), hillslope BMPs, THPs and modelling of sediment routing in watersheds are essential to avoiding sedimentation and turbidity problems. Thus the emphasis should initially be on source control at the watershed scale, which then can be monitored within the channels network. This is an issue that will be considered in more detail in response to the third and fourth questions in the SOW.

3.14 A further issue is the lag-time in sediment transfer systems which dictates that the effects of forest management practices and other disturbances on parameters such as percentage fines in spawning gravels, V* etc. may take several years or even

decades to respond to land use change in the watershed. Consequently adaptive management would is more ideally served by separating short-term impact metrics with longer-term ones. In the case of the former, emphasis on more rapidly responding indicators such as stream turbidity which would be indicative of adverse forest operations impacts and could prompt changes in THP through adaptive management. In the case of the longer-term responses, a more geomorphologically-based approach to sediment assessment and instream habitat could focus on establishment of monitoring reaches where long-term changes in the channel thalweg profiles could be used as a framework to integrate numerous metrics relating to channel morphology (see Madej, 1999b).

3.15 Whilst the metrics used in the indicators for sediment and turbidity problems generally relate to well-established protocols, once again, the use of static values does not link in well with the high level of spatial and temporal variability that can be anticipated. Thus, whilst the adverse effect of fines on ova development and fry emergence are generally well-documented, there is little consensus on a critical threshold of percentage fines or indeed for what grain size is the limit for the definition of "fine". For many northern Californian streams, Lisle and Hilton (1992) note that fine sediment loads are naturally high in many streams due to the high degree of tectonic activity which ensures relatively high levels of sediment delivery, and the prevailing geology which contains numerous fine grained strata. Also, there seems to be no particularly good reason why pool-riffle breaks on streams with <3% gradient are the most appropriate locations for sampling for fine sediments. Similarly, a geometric mean diameter of >20mm for spawning gravel for salmonids whilst an attractively simple metric, ignores the fact that salmon will spawn in a wide range of fluvial sediments (Kondolf and Woolman, 1993). Other measures such as the Fredle Index, V*, the use of scour chains and pebble counts are similarly overly simplistic. A more integrated, geomorphologically-based approach to stream channel sediment assessment (see above) could be used a more integrated means of assessing the impact of enhanced sediment delivery on aquatic systems.

3.16 I am not sure of the logic of a metric which proposes "no visible increase" in turbidity in streams due to timber operations in Class I, II & III water courses. As turbidity or suspended sediment concentrations are relatively easy to measure, and the impacts on aquatic organisms and habitats are reasonable well known (eg Sigler *et al.*, 1984; Newcombe and MacDonald, 1991), it seems odd to prescribe a whole series of quantitative sedimentary indicators and then have a subjective/qualitative measure of an indicator of such key significance. Also, as Class III water courses have limited riparian protection it is difficult to envisage a situation when forestry operations have no impact on turbidity. One would anticipate that traditional harvesting operations would increase the risk of hillslope mass movement, which can cause major sediment delivery problems, and create tractor trails/yarding areas that will produce fine sediments during storm events despite attempts to control mobilization (Sidle *et al*, 1991; Lewis, 1998). This is a key area where the Matrix must be related to THPs through the Watershed Analysis and the HCP if adverse impacts on salmonid habitat are to be avoided. It is also important that numeric targets for turbidity reflect not only suspended sediment concentrations and loads, but also the duration of levels above thresholds which may be damaging to salmonids.

3.17tion/nutrient metrics are not specific in the Matrix restricting prescriptions to a qualitative requirement for "low levels" of chemical contamination and no excess nutrients. The leaching of nutrients following timber operations has been widely observed, thus increases in nutrient fluxes in stream waters can be anticipated and in certain circumstances could have significant ecological effects (Dahlgren, 1998).

Habitat access

3.18 Clearly the principle of ensuring physical access for fish passage is not compromised by forest operations or infrastructure is eminently sensible and relatively easily realized by careful road management and culvert design.

Habitat elements

3.19 Just as the avoidance of sedimentary problems is best treated at source, so to is the protection of habitat elements and channel conditions. Fundamental to this is the recognition that aquatic habitat elements, their associated stream channel and complex of riparian floodplain/wetland habitats are best managed in an integrated manner. Thus maximum protection should be afforded to riparian buffers fringing all three types of stream channel (Reid and Hilton, 1998). Of particular concern is the limited protection afforded to Class III stream channels. These represent major hydrological and sedimentary source areas, as well proving major inputs of LWD to the stream channels network (Keppler and Brown, 1998). Although such protection may not be sufficient to prevent large sediment inputs to river channels from major debris torrents, adequate riparian protection, together with sensitive management of vulnerable hillslopes will minimize the potential adverse impacts on aquatic habitats.

3.20 The suite of habitat elements found in a given watershed will reflect its environmental characteristics, as well as its land use history. Thus once again the notion of single values for particular habitat elements is over-simplistic and management would be better served by a range or distribution of parameter values which would reflect the diversity of habitat units that would be expected in a "properly functioning" aquatic system. Thus, substrate conditions will vary with channel type within watersheds (Montgomery *et al.,* 1995a). Maintaining the appropriate range of channels and substrate distributions that would be naturally found in a particular watershed is important in maintaining appropriate habitat for different fish species at different life stages (Montgomery *et al.*, 1999).

3.21 The unique role of large redwoods in creating extensive and long-lived LWD accumulations in streams has been documented by Keller *et al.* (1995). The importance of maintaining recruitment of large, old redwoods to maintain LWD in aquatic habitats therefore requires adequate riparian protection. Whilst the metrics used for LWD targets in the matrix relate to literature values for other systems in the Pacific north west, these are lower than those identified in redwood stands (Keller *et al.,* 1995; Lisle and Napolitano, 1998; Lisle, 1999). Consequently, levels of habitat complexity based on metrics in the Matrix can be expected to be much poorer than

natural systems. Clearly these metrics should be reassessed by drawing on the extensive expertise of scientists working on channels in the redwood region.

3.22 The frequency of pools in coastal redwood systems is high due to the influence of LWD. In channels with gradients >3% the metric appears reasonable. However, for less steep channels the target of target spacing of 6 channel widths appears to be too high. In studies of undisturbed systems pool spacings of 2-4 channel widths would be more realistic (Keller *et al*., 1995; Montgomery *et al*., 1995b). Furthermore, depth targets for pools seem to be too low. Work in Redwood Creek implies that much deeper pools occur and may occur and be required as refugia (Madej, 1999b). Moreover, the inadequate targets for pool spacing identified above will result in the targets for pool coverage being insufficiently low for "properly functioning" systems in the redwood region.

3.23 Maintaining existing off channel habitat is contingent upon adequate protection of the floodplain and riparian zone (Rot *et al.,* 2000; Welsh *et al.,* 2000). Identification and protection of the channel migration zone is therefore extremely important. Although specific metrics are not referred to in the Matrix, this issue is returned to in section 3.33 below,

3.24 Regarding habitat "hot spots" and refugia, in theory identifying the most sensitive parts of watersheds (key spawning areas, key refugia etc.) provides an appropriate focus for adaptive management. However, in the absence of empirical long-term data on aquatic communities it is difficult to see how these areas can be actively identified and protected at this stage.

Channel conditions and dynamics

3.25 Separating habitat elements from channel conditions and dynamics in the Matrix is probably unhelpful, as it is the continuum of hillslope processes – channel dynamics that maintains habitat elements. A clear conceptual understanding of these linkages provides a framework for a more integrated approach to monitoring (see Lewis, 1998; Ziemer, 1998b; Lisle, 1999).

3.26 The metrics used here are justifiable so long as index streams are available to establish targets for indicators such as the W:D ratio in a "properly functioning" stream. Again, W:D ratios will exhibit marked spatial variability within river channels, both between catchments with differing environmental characteristics and within the same watershed in response to general longitudinal changes the impact of localised influences such as LWD dams etc. Thus it is important that suitable W/D ratios are maintained for specific channel types within the watersheds and that an appropriate habitat distribution is maintained for utilization at different life stages (Montgomery et al., 1999). Similarly, restricting erosion to <10% of length appears reasonable, so long as areas of erosion are in areas where it would be naturally expected, rather than where accelerated for example from landsliding.

3.27 Maintaining floodplain connectivity is a sound principle, but one that is contingent upon a well protected riparian zone and adequate delineation of the

channel migration zone. As noted in 3.23 above, specific metrics are not used in this part of the matrix but the issue links in with discussion in 3.33.

Flow hydrology

3.28 It is unclear from the Matrix what is meant by the statement that watershed hydrography should indicate flow parameters "comparable to an undisturbed watershed" of similar characteristics. Does this mean identical or similar? If it is the former, basic forest hydrology theory would tell us that unless forestry operations are restricted to a relatively small (ca. <20%) and insensitive part of the watershed over relatively long (>decadal) timescales this is an unrealistic objective. If it is the latter interpretation, then the degree of change that is deemed acceptable needs to be identified and based on empirical understanding of minimal ecological impacts.

3.29 The extensive studies at Casper Creek have documented some of the hydrological effects of logging operations in the redwood region (Ziemer, 1998c; Keppler, 1998). Thus impacts of particular types of storm events, summer low flows and watershed hydrological pathways can be predicted in a general sense for the Redwood region. Moreover the variability of response to impacts observed at Casper provides a basis for prediction envelopes that can be used to guide management objectives. Certainly substantial deviation from the natural flow regime can be expected to affect aquatic organisms such as salmonids.

3.30 Similarly, the notion of zero increase in drainage network due to roads is again difficult to square with hydrological theory. Even with storm proofing and sediment conservation measures, both permanent and temporary (tractor trains, yarding areas etc.) road networks used during forestry will change catchment hydrological pathways with the consequence that flow regimes will probably be in some way modified.

Watershed conditions

3.31 Clearly storm proofing, proper maintenance and, where appropriate, decommissioning of forest roads is key to preventing adverse fine sediment delivery and increasing drainage densities during storm flows. However, there are no formal metrics for appraising the effectiveness of such management in the Matrix. Obviously they will relate to other pathways such as hydrological change etc., but this is just one example of the lack of integration of various indicators within the Matrix.

3.32 It is not clear how the metric for assessing disturbance history and the production of a disturbance index will operate. However, from the HCP it appears that a simple index based on assumed linear relationships is likely to be used as a basis for THPs. It is unlikely that such a simplistic index would be anything other than an extremely crude tool for assessing the suitability of potential forest operations in watersheds with significant cumulative impacts (Reid, 1998). Metrics that can be related to cumulative impacts in a meaningful way are key to providing a basis for prioritising management responses in watersheds (Scientific Review Panel, 1999).

3.33 As stressed above, maintaining adequate riparian buffers is key to any attempt to establish a "properly functioning" aquatic habitat. The rather complex range of numeric objectives specified in Attachments E and F, together with the limited protection which appears to be afforded to buffers within the HCP, seems a poor substitute to establishing wide, well-maintained buffers if the maintenance of channel and flooplain habitats is a serious objective (Science Review Panel, 1999). Also key to this is protection of Type III channels and their buffer zones to avoid downstream propagation of hydrological and geomorphological impacts. In this context, the concerns of Professor David Montgomery of the University of Washington, an international authority on the geomorphology of forested watersheds, are particularly pertinent (Montgomery, 1998). That a scientist of Professor Montgomery's stature and experience of the Pacific North West is concerned about the level of riparian protection afforded by the HCP and the subsequent implications for LWD recruitment and river channel habitat casts grave doubt over the levels of protection currently planned. It also calls in to question the appropriateness of the metrics cited in the Matrix. Without these being adequate, it is difficult to see the "properly functioning" target for aquatic habitats as being a realistic objective. Moreover, it is notable that Reid and Hilton (1998) call for a conservative approach to buffer protection and highlights of the influence of upslope processes (e.g. tree fall) on the buffer itself and the recruitment of LWD into the stream channel.

4 Which metrics are the most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate species in coastal redwood systems?

3.34 Unfortunately there is no simple, uniform answer to this question which can be applied at the regional scale. Rather, individual watersheds need to be considered; the watershed characteristics and current habitat conditions need to be identified and related to an assessment of salmonid population parameters (size, organization, structure, distribution etc.). Particular issues pertinent to each watershed can be identified, including areas of good and poor habitat and realistic targets set for habitat protection and improvement, based on past, current and future cumulative impacts. Such an approach is ambitious but consistent with the goal of protecting endangered salmon stocks. It is important that such an assessment and monitoring programme comprises a structured, nested approach to examining habitat indicators at a range of spatial (e.g. watershed, sub-basin, channel reach, habitat unit) and temporal (storm event – decadal) scales.

3.35 The process of Watershed Analysis, if carried out in a comprehensive and open manner, and allied to detailed empirical observations of particular system, offers a possible way towards an integrated framework for watershed management (Mongomery et al. 1995c). Considerable effort has been invested in developing clear, robust conceptual models of watershed functions by various researchers in Northern California. As Ziemer noted (1998b), its is difficult to envisage the complex set of interacting variables which influence salmonids simply being reduced into some key measure which will provide a basis for adaptive management of coastal redwood systems.

3.36 Nevertheless, conceptual models of ecosystem function allow the key relationships between management activities and aquatic habitats to be identified and understood for particular watersheds. With the aid of Watershed Analysis, involving both field surveys and GIS application, such models can establish the key issues in a particular watershed. Such analysis must be viewed as being flexible, iterative and engaged with watershed data at a range of significant spatial and temporal scales. An interdisciplinary group, including broad stakeholder representation, could be established for particular watersheds to analyse the available data and draw up a series of environmental targets. The geographical uniqueness of individual watersheds, although not well matched to the expedient of simple legislative protection, is an environmental reality which needs to be recognised if the protection of salmonids is to be a serious objective. Thus, the Matrix can be used as a point of departure in this analysis, but must be recast and tailored to the needs of a particular watershed and the management trajectory ideally needs to be far more proactive and long-term than that currently envisaged in the HCP. The work of the Watershed Analysis needs to be peer-reviewed and explicit protocols established for how the feedback loops will operate to continue to inform management decision making over both long and short timescales. Whilst presenting obvious political difficulties, such a level of engagement is required if the protection of endangered salmonids is to be a serious objective.

3.37 It is important to also recognise that the Washington approach to Watershed Analysis which the HCP is based upon is not does not have the specific aim of linking

management to legally protected endangered species. Thus, data collection on the size, structure and distribution of salmonid stocks in various watersheds is an urgent requirement. Such field observations will provide baseline habitat conditions to be assessed in the context of a biological response. Moreover, they may also provide a basis for establishing empirical relationships that indicate a measure of ecosystem functioning in relation to watershed management and cumulative impacts (see Lewis, 1998). Though it recognised that this is a difficult task and requires extensive data collection, it is a key research and management priority in terms of successful use of the Matrix (Science Review Panel, 1999).

3.38 In summary, it is not so much an issue of establishing metrics for assessment, monitoring and adaptive management, but an issue of establishing operational frameworks where all three activities can be undertaken in the context of a particular watershed. Again, the pathways and indicators in the Matrix provide a useful starting point, but must be considered in the context of a sound conceptual understanding of the issues, functioning and habitat quality/potential in a particular basin. Such interrelationships need to be viewed over both a range of nested spatial scales and over long and short timescales. The Watershed Analysis also needs to be closely allied to the concept of risk associated with various timber harvesting activities (such as percentage of watershed area harvested over specific timescales). Where adverse impacts are observed or predicted their needs to be a clear mechanism for rapid feedback to modify management practices in the THP in an adaptive manner to protect endangered salmon stocks. As it stands, it is unclear how such an operational framework is going to function.

5 *How should in-stream and riparian metrics be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression?*

3.39 Providing the broad-scale GIS work is complemented by detailed field observation, the Watershed Analsysis approach also offers considerable potential for identifying functional linkages of watershed and hillslope-scale processes with in-stream and riparian conditions. Central to this is the importance of viewing the Watershed Analysis as an on-going, iterative process that will develop a conceptual understanding of individual watersheds, which identifies the key linkages between watershed processes and aquatic habitats. Only in this way can the Matrix be combined with the Watershed Analysis to achieve the adaptive management which is required to promote more sustainable forest practices. At present there is a danger that the Watershed Analysis becomes restricted to a broad GIS exercise that does not adequately provide a basis for adequate watershed, hillslope and river channel management. In this context, I share many of the concerns voiced by Montgomery (1998) over the degree to which the HCP will avoid adverse impacts on watershed processes and salmonid populations through the management of hillslope – channel linkages.

3.40 In many ways achieving this linkage is central to maintaining "properly functioning" habitat conditions in riparian and stream channel systems. Thus, the potential lack of protection given to riparian zones of Class I, II and III streams within the HCP is a matter of serious concern. Notwithstanding the targets for riparian conditions specified in attachments E and F of the matrix, it is clear from the HCP that the riparian areas could continue to be subject to considerable pressures from forestry operations. These include the possibility of very narrow no cut zones, selective harvesting of many of the larger trees, very limited protection to Class III zones (which for major hydrological, sedimentary and LWD source areas) and an inadequate definition and subsequent level of protection given to the channel migration zone.

3.41 Moreover, despite the protocols, there are real difficulties in accurately predicting landslide frequency and occurrence in watersheds where tectonic events, large storm episodes and cumulative impacts of past, current and future management underpin highly active geomorphological systems. Thus, the occurance of hillslope mass movements are not restricted to the areas where standard terrain analysis is likely to predict them.

3.42 The consequences of current levels of protection dictate that downstream effects of forest operations on hillslope and riparian processes are likely to adversely affect salmonid populations unless a more conservative approach is adopted. This will need to be based on detailed habitat assessment in the field and adopt precautionary measures for protection. In many watersheds these are likely to define significant proportions of the riparian zone and hillslopes as no cut areas and thus significantly reduce the extent and/or rate of harvesting in the hish risk areas of sensitive watersheds. Ultimately, precautionary management of hillslope and riparian zones, by limiting felling areas in this way, is probably the only way of protecting salmonid habitat in a manner consistent with conserving endangered salmon stocks.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 The Matrix is a potentially useful starting point for protecting salmonid habitat in the watersheds covered by the HCP. It contains a group of metrics for appropriate influence pathways and habitat indicators that are relevant to salmonids in the Pacific north west.

4.2 Unfortunately the Matrix has some serious methodological flaws:

> It considers habitat indicators in isolation and therefore provides a limited basis for the integrated approaches needed to manage complex interactive watershed systems.
>
> The Matrix essentially provides a range of metrics, which whilst generally applicable at the regional scale, are not sufficiently well-matched to the spatial and temporal variability within and between watersheds covered by the HCP.
>
> The spatial and temporal scales at which target indicators are relevant is often unclear in the Matrix.
>
> Empirical data on the size, structure, and distribution of salmonid fish in the area covered by the HCP is scarce. Thus the linking of habitat metrics to these biological targets is not empirically based.
>
> The notion of risk is not explicit in the Matrix or HCP. Thus, the spatial and temporal variation of risk to salmonid habitat resulting from forestry operations is not clear.
>
> The lack of integration of habitat indicators in the Matrix dictates that the effects of cumulative impacts on salmonid habitats are poorly considered.
>
> The Matrix appears to have no mechanism for incorporating information from new research or monitoring programmes to improve the metrics listed.
>
> There is no clear procedure for feedback loops from the Matrix targets to monitoring programmes and then to adaptive management of forested watersheds.

4.3 If the Matrix is therefore to provide a useful starting point for the protection of salmonid habitat in the area covered by the HCP, it needs to be reconsidered and clearer methodological links to the HCP and THPs need to be forged.

4.4 Watershed Analysis provides a basis for doing this, providing that this is seen as an iterative, ongoing process which combines relatively coarse GIS analysis with the collation of new empirical data on watershed conditions, habitat variables and salmon populations.

4.5 Conceptual models of the key interactions in particular watersheds need to provide a basis for understanding the condition of instream and riparian habitat, together with fish population data.

4.5 For designated watersheds, nested monitoring programmes, which examine watershed processes at the basin scale and at monitoring reaches and habitat units can provide a basis for a watershed management group to ensure that the methodologies proposed in the HCP can be integrated to provide a basis for adaptive management.

4.6 Central to the maintenance and restoration of salmonid habitat in watersheds is the adequate protection of riparian buffer zones and channel migration zones. By protecting the channel network and buffering aquatic habitat from land management elsewhere in the catchment many of the risks associated with forestry operations can be minimised. As it stands there are indications that the levels of protection afforeded by the HCP are insufficient.

4.7 Though this may have difficult political and economic implications regarding the extent and frequency of forestry operations in particular watersheds, such a precautionary approach may well be the only way in which the protection of the habitat of endangered salmonids can be seriously advanced.

APPENDIX A: STATEMENT OF WORK

General

In March 1997, federal and state agencies developed an aquatic matrix for the Pacific Lumber Company Habitat Conservation Plan (hereafter "salmon matrix"). The matrix puts forth a condition for the landscape which has been determined to be properly functioning in order to meet the habitat needs of anadromous salmonids and other aquatic species in northern California on Pacific Lumber Company properties in Humboldt County.

Consultants shall need to address the following questions for the salmon matrix review:

1. Are the metrics used in the matrix appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species? If not, which metrics would be appropriate and at what landscape scales?

2. Are the values provided for the metrics appropriate for assessing aquatic and associated riparian habitat condition to meet the needs of threatened and candidate salmonid species in coastal redwood systems? If not, which values would be appropriate and at what landscape scales?

3. Which metrics are the most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate salmonid species in coastal redwood systems?

4. How should in-stream and riparian metrics be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression?

Specific

The consultant's duties shall not exceed a maximum total of three weeks- several days for document review, a 4-day meeting, and several days to produce a written report of the findings. Please note that the report produced must be based on the consultant's individual opinions of the science in his area of expertise and not that of the group; thus, no consensus report shall be produced.

The itemized tasks of the consultant include:

1. Reading and analyzing the relevant documents provided to the consultant;

2. Participating in a 4-day meeting with the other consultants and NMFS officials in San Francisco/Arcata, CA, from November 27-30;

3. No later than January 15, 2001, submitting a written report of findings, analysis, and conclusions. The report should be addressed to the "UM Independent System for Peer Reviews, " and sent to Dr. David Die, UM/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149 (or via email to ddie@rsmas.miami.edu).

APPENDIX B: ADDENDUM TO STATEMENT OF WORK

November 22, 2000

This addendum is not to replace the contents of the original statement of work or the questions that the reviewers are to consider. It is, however, meant to clarify some of the questions that the reviewers are to address when conducting the review and completing the review report. Most importantly, the reviewers should consider the two following points:

1. In question 3 on the Statement of Work, reviewers are asked to consider which metrics are most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate salmonid species in coastal redwood systems. The reviewers are to incorporate their findings from question 1, which asks whether the metrics used in the matrix are appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species, and if not, then which metrics would be appropriate and at what landscape scale. These findings from question 1 may provide a subset of metrics that are appropriate for the specific habitats in coastal redwood systems. If there are other metrics that are more appropriate and not used in the matrix, the reviewers may address these as well.

2. In addition to question 4 on the Statement of Work, the following question may assist the reviewers on addressing the applicability of the matrix framework:

   Does the matrix framework provide adequate tools and guidelines for stream and riparian metrics to be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression? If not, what additional features, properties, or guidelines should be addressed to the matrix framework?

APPENDIX C: SALMON MATRIX REVIEW-RELATED LITERATURE

MATRIX CITED LITERATURE

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OTHER DOCUMENTS

33. Public/Private Comments on Matrix for Pacific Lumber HCP (INCLUDES SEVERAL COMMENTS)

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APPENDIX E: PRESENTATIONS ON FIRST DAY OF REVIEW MEETING

Structure of the PALCO HCP – John P. Clancey & Sam Flanagan

Regional salmonid species status – Greg Bryant

Development of the role of the matrix in the PALCO HCP – Bill Condon

Description of local geology and stream channel form and function – Sam Flanagan

Sediment and turbidity regimes in local watersheds – Bill Trush

Large Woody Debris surveys and stream channel function – Randy Kline

Discussion on indicators of salmonid habitat health – Randy Kline

APPENDIX F: ADDITIONAL MATERIAL CONSULTED AND CITED IN THE REPORT

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