Methodology to a Watershed Based Approach to Clean Water and Natural Resource Management

Part II

Characterize Condition of Ecological Processes in Study Area

PART II. CHARACTERIZE CONDITION OF ECOLOGICAL PROCESSES IN STUDY AREA

Goal

One central goals of watershed characterization is to identify natural resource areas that could serve as restoration sites to mitigate impacts of the built environment. Another goal is to identify and provide a list of potential natural resource sites that have high preservation or protection value. For the purposes of this work, the following definitions are utilized (Horner 2010)

> Restoration—*any* level of improvement in ecological condition, with no connotation of necessarily returning the system to its original state of pre-human influence (some literature terms partial restoration as “rehabilitation” or “enhancement”); and
>
> Preservation (or protection)—retaining the ecological state at its existing level, whatever that may be, without diminishing any indicators of the health of that state,

Purpose

Characterizing the condition of important ecological processes is intended to produce results that can be used to:

- Help understand the landscape-scale condition of and constraints on aquatic and terrestrial resources and fish and wildlife habitats ;
- Establish a landscape context for assessing restoration options and alternatives;
- Help identify where landscape-scale causes of natural resource degradation exist, providing context for understanding restoration opportunities and limitations at a site scale;
- Help understand core problems that influence a site’s capability to provide and maintain functions; and
- Evaluate habitat connectivity within stream basins and identify opportunities for restoration.

Methods

Thurston County’s methods utilize the Matrix of Pathways and Indicators (MPI) developed by the National Marine Fisheries Service (NOAA Fisheries) (Stelle 1996), and NOAA Fisheries Service. March, 2003. HCD Stormwater Online Guidance: ESA Guidance for Analyzing Stormwater Effects. NOAA Fisheries Service, Northwest Region (Table 2)

For each of the ecological processes listed in the MPI, Thurston County used the specific indicators that were compiled and analyzed to define the DAUs status as "properly functioning", "at risk" and "not properly functioning".

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Following completion of each watershed characterization, Thurston County staff completed a scientific literature review. After the reviews,, it was determined that the values stated in the MPI are still appropriate.

The results of the five ecological processes were analyzed and reported at the DAU scale. If a specific indicator was not available, it was documented as a N/A (e.g., water quality data).

The following summarizes the steps to complete the Totten and Eld Inlets and Deschutes River watershed characterizations:

Step 1. Movement of Water

To characterize the delivery of water, Thurston County:

- Calculated percent TIA for each DAU using the current landcover data.
- Calculated percent forest and prairie landcover for each DAU using the current landcover data.
- Determined the condition and extent of wetlands in DAU's where wetlands were present. Calculated percent of wetlands hydrologically altered (drained or filled) within each DAU.
- Used the Rain on Snow Zone data available through WDNR in watersheds where it is appropriate.

To characterize the routing of water, Thurston County:

- Calculated the percent stream channel length straightened for each DAU by overlaying hydrography datasets onto the drainage basin coverage and visually identified stream reaches that had potentially been straightened. Stream reaches with native vegetation were assumed to have a natural stream configuration and were eliminated from further consideration as a restoration site. In contrast, stream reaches with agricultural, high density residential, or commercial/industrial land uses were assumed to have an artificially straightened stream reach. Aerial photography and LiDAR were used to support decision-making where uncertainty existed. GIS tools were used to calculate the percentage of stream channel that has been straightened.
- Calculated the percent of floodplain decoupled from the river channel for each DAU by acquiring available data on the location and extent of floodplain dikes and levees. Where local data was not available, LiDAR was used to identify that part of the floodplain that lies behind dikes and levees. A GIS layer was then used to calculate the percentage of floodplain area that was decoupled.

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Step 2. Movement of Wood

Delivery of Large Wood

To characterize the delivery of large wood, Thurston County:

- Determined the percent of 67 meter riparian zone in mature forest for each drainage basin, using a fixed-width buffer zone around each mapped stream intersected with the GIS landcover layer.
- Calculated the percent stream channel length straightened for each DAU by overlaying hydrography datasets onto the drainage basin coverage and visually identified stream reaches that had potentially been straightened. Stream reaches with native vegetation were assumed to have a natural stream configuration and were eliminated from further consideration as a restoration site. In contrast, stream reaches with agricultural, high density residential, or commercial/industrial land uses were assumed to have an artificially straightened stream reach. Aerial photography was used to support decision-making where uncertainty existed. GIS tools were used to calculate the percentage of stream channel that has been straightened.
- Calculated the percent of floodplain decoupled from the river channel for each DAU by acquiring available data on the location and extent of floodplain dikes and levees. Where local data was not available, LiDAR was used to identify that part of the floodplain that lies behind dikes and levees. A GIS layer was then used to calculate the percentage of floodplain area that was decoupled.

> Thurston County does have a bridge/culvert inventory with structure crossing width data; however, it does not contain all the required data to utilize this indicator. That would have required field verification to determine the ordinary high water mark for each crossing, and thus was not completed as part of this work. However, for any future site specific natural resource restoration actions, that data should be collected and used in the analysis of potential restoration of resource sites.

Routing of Large Wood

To characterize the routing of large wood, Thurston County:

- Determined the average number of stream crossings per kilometer of stream for each DAU by intersecting the roads and stream layer. If field data or engineering designs were independently available, the average stream bed width and size of crossing, including the number of piers in the active channel, were determined by non-GIS means.

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Step 3. Movement of Sediment

NOTE: The delivery and routing of sediment analysis is only appropriate for long-term forestry areas, and is not appropriate to use in the urban areas.

Delivery of Sediment

NOTE: The delivery and routing of sediment analysis is only appropriate for long-term forestry areas. It is not appropriate to use in the urban areas.

To characterize the delivery of sediment, Thurston County:

- Using the most current land cover information, calculated the percentage of bare soil areas within each DAU.
- Calculated the percent of unstable slopes in each DAU, using the existing state DNR data layers.

Routing of Sediment

To characterize the routing of sediment, Thurston County:

- Used GIS tools to calculate road density (road miles per square mile) for each DAU.
- Calculated the percent stream channel length straightened for each DAU by overlaying hydrography datasets onto the drainage basin coverage and visually identified stream reaches that had potentially been straightened. Stream reaches with native vegetation were assumed to have a natural stream configuration and were eliminated from further consideration as a restoration site. In contrast, stream reaches with agricultural, high density residential, or commercial/industrial land uses were assumed to have an artificially straightened stream reach. Aerial photography was used to support decision-making where uncertainty existed. GIS tools were used to calculate the percentage of stream channel that has been straightened.
- Calculated the percent of floodplain decoupled from the river channel for each DAU by acquiring available data on the location and extent of floodplain dikes and levees. Where local data was not available, LiDAR was used to identify that part of the floodplain that lies behind dikes and levees. A GIS layer was then used to calculate the percentage of floodplain area that was decoupled.
- Movement of Nutrients and Toxicants

Step 4. Movement of Pollutants

Delivery and Routing of Nutrients and Toxicants

- Although in principle the number of Clean Water Act (CWA) 303(d) listed water bodies for each drainage basin should be a useful indicator of the water quality, the limited number of ambient monitoring sites in Thurston County can only indicate what DAUs are “not properly functioning.” Many streams do not have ambient monitoring data and

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thus it can't be assumed that streams without data are "properly functioning." In the Totten and Eld Inlets and the Deschutes study areas, the utility of the CWA 303(d) list was greatly limited by data availability. The data was utilized when there was an ambient monitoring site in the DAU. If there was no data in a DAU, then the indicator was noted to be N/A.

- Determined the percent of 67 meter riparian zone in mature forest for each drainage basin, using a fixed-width buffer zone around each mapped stream intersected with the GIS landcover layer.

Step 5. Movement of Heat

Delivery and Routing of Heat

- To characterize the delivery and routing of heat, Thurston County used the 303(d) listed water bodies and percent of 67 meter riparian zone in mature canopy, in addition to TIA and road crossings to indicate conditions relative to stream-water temperature. Percent TIA and road crossings inferences were presented in the Totten and Eld Inlets and Deschutes watershed results, but the relevance of all but the buffer-zone metric (and 303d listings, where available) is uncertain (Booth, 2010). Therefore, percent TIA and road crossings have been deleted from the MPI, and will not be used in future watershed characterizations because of the lack of data that supports their inclusion in the MPI.

- Determined the percent of 67 meter riparian zone in mature forest for each drainage basin, using a fixed-width buffer zone around each mapped stream intersected with the GIS landcover layer.

Additional indicators include the following biological elements:

> Aquatic Integrity: Snyder et al. (2003) synthesized results of existing studies relating to the influence of upland and riparian land use patterns on stream biotic integrity. This paper notes that in studies where scale influences were tested, whole catchment land use patterns were found to be better predictors of stream biological integrity in some studies, while others suggest riparian land use patterns were more influential. Morley and Karr (2002) presented similar results specifically for the Puget Lowland. This information supports the use of both percent riparian area in forest landcover and percent total impervious area as landscape indicators of aquatic integrity, where direct biological data are unavailable.

Aquatic Integrity

To characterize Aquatic Integrity, Thurston County plotted and classified all available Benthic- Index of Biological Integrity (B-IBI) scores, % riparian, and %TIA within the study area. The corresponding scores were applied to the downstream only in the corresponding DAU, and not for the entire stream.

Where direct measurements of biological elements are unavailable, conditions can be inferred using other metrics. Criteria using the previously calculated condition results of

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percent riparian area in forest landcover and %TIA by DAU are shown in Table 2 as such example. Although percent riparian cover and percent total impervious area were not used as surrogates for this element in the prior studies, abundant research suggests it is likely very useful where no direct data are available and can be used in future watershed characterization work. However, future use of B-IBI data will include using the B-IBI scores to validate the condition of the DAU where there is data.

Step 6. Habitat Connectivity

To characterize habitat connectivity, Thurston County:

Used the software program FRAGSTATS; FRAGSTATS is a spatial pattern analysis program for quantifying landscape structure. The landscape subject to analysis is user defined and can represent any spatial phenomenon. FRAGSTATS quantifies the areal extent and spatial distribution of patches (that is, polygons on a map coverage) within a landscape; the user must establish a sound basis for defining and scaling the landscape (including the extent and grain of the landscape) and the scheme by which patches within the landscape are classified and delineated (we strongly recommend reading the preceding section, "Concepts and Definitions"). The output from FRAGSTATS is meaningful only if the landscape mosaic is meaningful for the phenomenon under consideration.

Matrix of pathways and Indicators

The Matrix of pathways and Indicators (MPI) was developed by NOAA Fisheries in 1996 (Stelle 1996) in response to the ESA listing of Chinook salmon. Initially, many of the indicators were qualitative only, and actual values were added as data and best professional judgment allowed. It should be noted that best available science supports many of the values, while other best available science does not. Because these values are used in a GIS analysis, and landcover classification accuracy is approximately 80%, the values used are appropriate for the scale of analysis.

Indicators in bold were used for Totten, Eld, and Deschutes watershed characterizations.

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Table 2. Matrix of Landscape-scale Pathways and Indicators (Stelle 1996)

Ecological Process	Landscape Indicator	Effect	Properly Functioning	At Risk	Not Properly Functioning
Delivery of Water Through a Stream System	1) Percent change in Drainage Network [i]	Reduces Delivery Time; Habitat Degradation	Zero or minimal increases (<5%) in drainage network density due to development Moderate increases (5% to 20%) in drainage network density due to development Substantial increase (>20%) in drainage network density due to development		
	2) Percent TIA [ii]	Reduces Delivery Time; Increases Amount of Water Delivered; Habitat Degradation	10% or less TIA	>10% and <25% total imperious area	≥25% TIA
	3) Percent Forest Landcover and/or prairie cover[iii]	Reduces Delivery Time; Increases Amount of Water Delivered; Habitat Degradation	>65% of area in hydrologically mature forested landcover or native prairie	50% to 65% of area in hydrologically mature forested landcover or native prairie	<50% in hydrologically mature forested landcover or native prairie
	4) Condition and Extent of Wetland Resources [iv]	Loss of assimilative capacity	>95% of all historic connecting wetland capacity present and unaltered	70-95% of historic connecting wetland capacity present and unaltered	<70% of historic connecting wetland capacity present and unaltered
	5) Rain on Snow				
Routing of Water Through a Stream System	**6) Percent of Stream Channel Length Straightened**	Reduced Routing Time; Habitat Degradation	Zero or minimal increases (<5%) of natural drainage network straightened	Moderate increases (5% to 20%) in natural drainage network straightening	Substantial increase (>20%) in drainage network straightening
	7) Percent of Flood-plain Decoupled from Stream [v]	Reduced Routing Time; Habitat Degradation	Zero or minimal increases (<5%) in decoupled flood-plain	Moderate increases (5% to 40%) in decoupled flood-plain	Substantial increase (>40%) in decoupled flood-plain
Delivery of Large Wood to a Stream System	**8) Percent of 67 meter Riparian Zone in Mature Condition [vi]**	Source of Large Wood to the Stream System; Habitat Degradation	85% of overall riparian zone in forest or wetland cover	50-85% of overall riparian zone in forest or wetland cover	<50% of overall riparian zone in forest or wetland cover
	9) Percent of Stream Channel Length Straightened	Reduced Routing Time; Habitat Degradation	Zero or minimal increases (<5%) of natural drainage network straightened	Moderate increases (5% to 20%) in natural drainage network straightening	Substantial increase (>20%) in drainage network straightening
	10) Percent of Flood-plain Decoupled from Stream [vii]	Reduced Routing Time; Reduced Access to Habitat	Zero or minimal increases (<5%) in decoupled flood-plain	Moderate increases (5% to 40%) in decoupled flood-plain	Substantial increase (>40%) in decoupled flood-plain
Routing of Large Wood Through a Stream System	**15) Stream Crossings/Kilometer [viii]**	Blocks Routing of Large Wood and Facilitates Removal from System; Habitat Degradation	< 2 –stream crossings per kilometer of stream and ratio of culvert width to channel width is >1	2 to 4 stream crossings per kilometer of stream and ratio of culvert width to channel width is 0.5 to 1	> 4 stream crossings per kilometer of stream and ratio of culvert width to channel width is <0.5
Delivery of Sediment to a Stream System	**11) Percent of Bare Soil Areas in agricultural and forest Areas**	Increased Fine Sediment Inputs; Habitat Degradation	<5% of area in land uses having bare soils	5-15% of area in land uses having bare soils	>15% of area in land uses having bare soils
	12) Road Density [ix]	Increased Fine and	Road densities < 1.0	Road densities of 1.0 to	Road densities > 1.6

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Ecological Process	Landscape Indicator	Effect	Properly Functioning	At Risk	Not Properly Functioning
		Coarse Sediment Inputs; Habitat Degradation	miles/square mile	1.6- miles/square mile	miles/square mile
	13) Unstable Slopes	Increased Inputs of Fine and Course Sediment	≥5% of DAU in > 30 percent slope and <10 percent of high slope area in non-forest landcover	≥5% of DAU in > 30 percent slope and ≥10%< 25% of high slope area in non-forest landcover	≥5% of DAU in > 30 percent slope and ≥25% of high slope area in non-forest landcover
Routing of Sediment Through a Stream System	**14) Percent of Stream Channel Length Straightened**	Reduced Routing Time; Habitat Degradation	Zero or minimal increases (<5%) of natural drainage network straightened	Moderate increases (5% to 20%) in natural drainage network straightening	Substantial increase (>20%) in drainage network straightening
	15) Percent of Flood-plain Decoupled from Stream [x]	Reduced Routing Time; Reduced Access to Habitat	Zero or minimal increases (<5%) in decoupled flood-plain	Moderate increases (5% to 40%) in decoupled flood-plain	Substantial increase (>40%) in decoupled flood-plain
Delivery and Routing of Nutrients, Toxicant, and Bacteria to a Stream System	**16) Extent of 303(d) Listed Water Bodies for Nutrients, Toxicants, and Bacteria** [xi]	Documented Water Quality Problem	Water quality in the stream meets water quality standards for all parameters. No excess nutrients or toxicity.	Water quality in the stream has one parameter that exceeds water quality criteria by 10 percent or greater	More than one parameter exceeds water quality criteria by 10 percent or greater.
	17) Condition and Extent of Wetlands [xii]	Loss of assimilative capacity	Historic wetland area >5% and <25% of wetlands have been drained or hydrologically altered	Historic wetland area 25% to 40% of wetlands have been drained or hydrologically altered	Historic wetland area >40% of wetlands have been drained or hydrologically altered
	18) Percent of 67 meter Riparian Zone with Mature Canopy [xiii]	Increase in Solar Energy to Stream; Habitat Degradation	85 percent or more of channel with riparian canopy intact and no large continuous stretches of open canopy	50 to 85 percent of riparian canopy intact but having some continuous stretches of open canopy	Riparian canopy fragmented, > 50 percent and contains large continuous stretches with no canopy
Delivery and Routing of Heat to a Stream System	**19) Extent of 303(d) Listed Water Bodies for Temperature** [xiv]	Identifies Problem Areas but Does Not Address Causes; Habitat Degradation	Area meets water quality standards for temperature	One parameter that exceeds temperature criteria 10 percent or more of the time	More than one parameter exceed temperature criteria 10 percent or more of the time
	20) Percent of 67 meter Riparian Zone with Mature Canopy [xv]	Increase in Solar Energy to Stream; Habitat Degradation	85 percent or more of channel with riparian canopy intact and no large continuous stretches of open canopy	50 to 85 percent of riparian canopy intact but having some continuous stretches of open canopy	Riparian canopy fragmented, > 50 percent and contains large continuous stretches with no canopy
Biological Elements					
Upland Habitat Connectivity	**21) Level of Habitat Connectivity**	Risk of Habitat Isolation	Use methods described elsewhere using Fragstats	Use methods described elsewhere using Fragstats	Use methods described elsewhere using Fragstats
Watershed Condition Index (See below)	22) Coho:Cutthroat Ratio				

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Staff met with Jamie Glasgow on the possibility of capturing coho:cutthroat data to begin to develop a simpler matrix; Jamie had the following comments;

Jamie Glasgow, Wild Fish Conservancy, states:

“My concerns with relying solely on the coho:cutthroat ratio as an indicator for WCI are outlined below. Considered with other metrics and a healthy dose of common sense, the ratio can be useful - but lacking those two things it can be misleading.

Due to the complex nature of their life cycle, coho abundance in watersheds is only partially controlled by the integrity of the watersheds they use. You can have a watershed that is pristine, but has only a fraction of the coho abundance it did historically due to harvest, hatchery interactions, ocean conditions, etc. This may be especially true in south Puget Sound, where stray hatchery coho make up a significant portion of the coho we see spawning in area streams.

Coho abundance is disproportionately affected by instream barriers. Again, you can have an intact watershed with one barrier to anadromy

Tables 3 through 8 contain the rules and assumptions developed to complete the ranking of the five ecological processes and habitat connectivity. These assumptions are based on the goal of identifying sites that have the potential mitigate past and future impacts from development.

Table 3. Rules and Assumptions Used to Establish the Overall Condition Rank for Movement of Water

Indicator Priority	Landscape Indicator	Condition	Final Rank
Primary	%TIA	When % TIA is PF and % forest/prairie cover are PF, % stream channel length straightened is PF or AR, and wetlands or floodplains are not indicators, the final rank is PF	PF
Secondary	% Forest cover/Prairie cover	When % TIA is PF and % forest/prairie cover are AR or NPF, % stream channel length straightened is PF or AR, and wetlands or floodplains are not indicators, the final rank is AR	AR
Secondary	% Stream channel length straightened	When % TIA is AR and % forest/prairie cover is PF, % stream channel length straightened is AR or NPF, and wetlands and floodplains are not indicators, the final rank is AR	AR
Tertiary	Condition/extent of wetlands. Assimilative capacity	When % TIA is NPF and % forest/prairie cover is AR or NPF, % stream channel length straightened is AR or NPF, and wetlands or floodplains are not indicators, the final rank is NPF	NPF

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Indicator Priority	Landscape Indicator	Condition	Final Rank
Tertiary	% Floodplain decoupled from the channel	When % TIA is PF, % forest/prairie cover is PF, % stream channel length straightened is PF or AR, and wetlands and floodplains are PF, the final rank is PF	PF
		When % TIA is PF, % forest/prairie cover is PF, and wetlands or floodplains are AR or NPF, the final rank is AR	AR
		When % TIA is AR, % forest/prairie cover is AR or NPF, wetlands and floodplains are AR or NPF, the final rank is AR	AR
		When % TIA is NPF, % forest/prairie cover is AR or NPF, wetlands or floodplains are AR or NPF, the final rank is NPF	NPF
		When % TIA is PF, % forest/prairie cover is AR or NPF, and wetlands or floodplains are AR or NPF, the final rank is AR	AR
		When % TIA is AR, % forest/prairie cover is NPF, wetlands or floodplain are AR or NPF, the final rank is NPF	NPF
		When % TIA is AR, % forest/prairie cover is AR or NPF, wetlands or floodplains are PF, the final rank is AR	AR
		When % TIA is AR and % forest/prairie cover is AR, and wetlands or floodplains are not indicators, the final rank is AR	AR

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Table 4. Rules and Assumptions Used to Establish the Overall Condition Rank for Movement of Wood

Indicator Priority	Landscape Indicator	Condition	Final Rank
Primary	% of 67 m riparian zone in mature condition	When % riparian is PF, % stream channel straightened and stream crossings are PF, the final rank is PF	PF
Secondary	Stream crossings/kilometer	When % riparian is PF, % stream channel straightened and stream crossings are AR, and % floodplain decoupled is AR or NPF, the final rank is AR	AR
Secondary	% stream channel straightened	When % riparian is AR, % stream channel straightened, stream crossings and % floodplain decoupled is PF or AR, the final rank is AR	AR
Tertiary	% floodplain decoupled	When % riparian is AR, % stream channel straightened, and stream crossings are AR or NPF and % floodplain decoupled is AR or NPF, the final rank is NPF	NPF
		When % riparian is NPF, % stream channel straightened is AR, and stream crossings are AR or NPF, the final rank is NPF	NPF
		When % riparian is PF, % stream channel straightened and stream crossings are PF or AR, and % floodplain decoupled is not an indicator, the final rank is PF	PF
		When % riparian is AR, % stream channel straightened and stream crossings are PF or AR, and % floodplain decoupled is AR the final rank is AR	AR
		No indicators in the DAU, the final rank is N/A	N/A

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Table 5. Rules and Assumptions Used to Establish the Overall Condition Rank for Movement of Sediment

Indicator Priority	Landscape Indicator	Condition	Final Rank
Primary	% Bare soil	When bare soils and road density are PF and geologic hazard areas are either PF or not present, the final rank is PF	PF
Secondary	Road density	When bare soils and geologic hazard areas are NPF or AR and road density is AR the final rank is NPF	NPF
Tertiary	% stream channel straightened	Where there are no bare soils or geologic hazard areas in the DAU; Where % stream channel straightened and % decoupled floodplain are PF and road density is AR or PF, the final rank is PF	PF
Tertiary	% decoupled floodplain	Where there are no bare soils or geologic hazard areas in the DAU; Where % stream channel straightened and % decoupled floodplain are AR and road density is NPF or AR the final rank is AR	AR
		Where there are no bare soils or geologic hazard areas in the DAU; Where % stream channel straightened and % decoupled floodplain are NPF or AR and road density is NPF or AR the final rank is NPF	NPF

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Table 6. Rules and Assumptions Used to Establish the Overall Condition Rank for Movement of Pollutants, Nutrients, and Bacteria

Indicator Priority	Landscape Indicator	Condition	Final Rank
Primary	CWA 303(d) list for toxicants (sub-lethal and lethal to fish); for nutrients, and/or for bacteria	If the stream reach within a DAU has water quality data and is listed, then the final rank will be NPF because of the legal requirement to meet WQ standards.	NPF
Secondary	Percent of 67 m riparian zone in mature condition	If the stream reach within a DAU has water quality data and is listed, and the % of 67 m riparian zone in mature condition is NPF or AR then the final rank is NPF	NPF
		If the stream reach within a DAU has water quality data and is listed, and the % of 67 m riparian zone in mature condition is PF or AR then the final rank is AR	AR
		If the stream reach within a DAU has no water quality data and is not listed, and the % of 67 m riparian zone in mature condition is PF then the final rank is PF.	PF
		If the DAU does not include a surface water body, the rank is N/A	N/A

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Table 7. Rules and Assumptions Used to Establish the Overall Condition Rank for Movement of Heat

Indicator Priority	Landscape Indicator	Condition	Final Rank
Primary	CWA 303(d) list for temperature	If the stream reach within a DAU has water quality data and is listed, then the final rank will be NPF because of the legal requirement to meet WQ standards.	NPF
Primary	% 67 meter riparian mature canopy	When there is no water quality data for the reach within a DAU data available and % riparian is PF, then the final rank is PF	PF
Secondary	% Forest Landcover and/or Prairie cover	When % riparian is PF and % Forest landcover and/or Prairie cover is AR, the final rank is PF	PF
		When % riparian is AR, and % Forest landcover and/or Prairie cover is PF or AR, the final rank is AR	AR
		When % riparian is AR, and % Forest landcover and/or Prairie cover is AR or NPF the final rank is NPF	NPF
		When % riparian is NPF, and % Forest landcover and/or Prairie cover is PF or AR the final rank is AR	AR
		When % riparian is NPF, and % Forest landcover and/or Prairie cover is AR or NPF the final rank is NPF	NPF
		When % riparian is NPF, and % Forest landcover and/or Prairie cover is NPF, the final rank is NPF	NPF
		No Riparian Zone	N/A

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Table 8. Rules and Assumptions Used to Establish the Overall Condition Rank for Habitat Connectivity

Indicator Priority	Landscape Indicator	Condition	Final Rank
Primary	FRAGSTATS Metrics	When metrics, % riparian and road crossings are PF, the final rank is PF	PF
Secondary	% 67 meter riparian forest cover	When metrics are PF, and % riparian is PF, and road crossings are AR, the final rank is PF	PF
Tertiary	Road crossings	When metrics are PF, with no riparian zone, and road crossings are PF, the final rank is PF	PF
		When metrics are PF, and % riparian is AR, and road crossings are PF or AR, the final rank is AR	AR
		When metrics are PF, and % riparian is NPF, and road crossings are PF or AR, the final rank is AR	AR
		When metrics, % riparian and road crossings are AR, the final rank is AR	AR
		When metrics are AR, with no riparian zone, and road crossings are PF or AR, the final rank is AR	AR
		When metrics are AR, and both riparian zone and road crossings are PF, the final rank is AR	AR
		When metrics are AR, and riparian zone is AR, and road crossings are PF or AR, the final rank is AR	AR
		When metrics are AR, and % riparian is NPF, and road crossings are PF, the final rank is AR	AR
		When metrics are AR, and % riparian is NPF, and road crossings are AR or NPF, the final rank is NPF	NPF
		When metrics, % riparian and road crossings are NPF, the final rank is NPF	NPF
		When metrics are NPF, and riparian zone is AR or NPF, and road crossings are PF, AR or NPF, the final rank is NPF	NPF
		When metrics are NPF, with no riparian zone, and road crossings arePF, AR or NPF, the final rank is NPF	NPF

[i] Narrative criteria for indicator condition taken from US Fish and Wildlife Service (1998), numeric criteria added by authors

[ii] Revised 4/09. Schueler, T.R., L.Fraley-McNeil, and K. Cappiella. Journal of Hydrologic Engineering, April 2009. pg 309-314. Revised 8/04 based on Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, M.G. Larson, and S.J. Burges. In Press. Reviving Urban Streams: Land Use, Hydrology, Biology, and Human Behavior. Journal of the American Water Resources Association.

[iii] NOAA Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA Fisheries Service, Northwest Region

[iv] NOAA Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA Fisheries Service, Northwest Region

[v] Narrative criteria for indicator condition taken from NOAA-Fisheries (1996) and US Fish and Wildlife Service (1998), numeric criteria added by authors

[vi] Adapted from NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

[vii] Narrative criteria for indicator condition taken from NOAA-Fisheries (1996) and US Fish and Wildlife Service (1998), numeric criteria added by authors

[viii] NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

[ix] Narrative and numeric criteria for indicator condition taken from NOAA-Fisheries (1996)

[x] Narrative criteria for indicator condition taken from NOAA-Fisheries (1996) and US Fish and Wildlife Service (1998), numeric criteria added by authors

[xi] Narrative criteria for indicator condition taken from NOAA-Fisheries (1996) and US Fish and Wildlife Service (1998)

[xii] NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

[xiii] Adapted from NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

[xiv] Based on common criteria established by NOAA-Fisheries (1996) and the U.S. Fish and Wildlife Service (1998) for chemical contamination/nutrients

[xv] Adapted from NOAA-Fisheries Service. March, 2003. HCD Stormwater Online Guidance, ESA Guidance for Analyzing Stormwater Effects. NOAA-Fisheries Service, Northwest Region

Peer Reviewed Final Draft