Assessment of Riparian Ecosystem Integrity: Otay River Watershed, San Diego County, California

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R. Daniel Smith
U. S. Army Engineer Research and Development Center
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1.0 Introduction

The Los Angeles District Corps of Engineers - Regulatory Branch is developing a Special Area Management Plan (SAMP) for the Otay River watershed in San Diego County, California (Figure 1). The SAMP is a comprehensive wetlands planning effort conducted in areas of special sensitivity. The goal of the SAMP is to…"develop and implement a watershed-wide aquatic resource management plan and implementation program, which will include preservation, enhancement, and restoration of aquatic resources, while allowing reasonable and responsible economic development and activities within the watershed-wide study area" (Los Angeles District Corps of Engineers 2000).

As part of the SAMP planning effort, the aquatic resources within the Otay River watershed were delineated and assessed. The report by Lichvar and Ericsson (2003) presents the methods and results of the aquatic resource delineation. This report presents the methods and results of the assessment of riparian ecosystem integrity. In addition, supplemental water quality, hydrology and (potentially) habitat studies will be performed. Other components of the SAMP include the development of the SAMP tenets, the purpose and need statement, an analysis of alternatives, a watershed restoration plan, the preparation of an Environmental Impact Statement (EIS), and finally the issuance of permits.

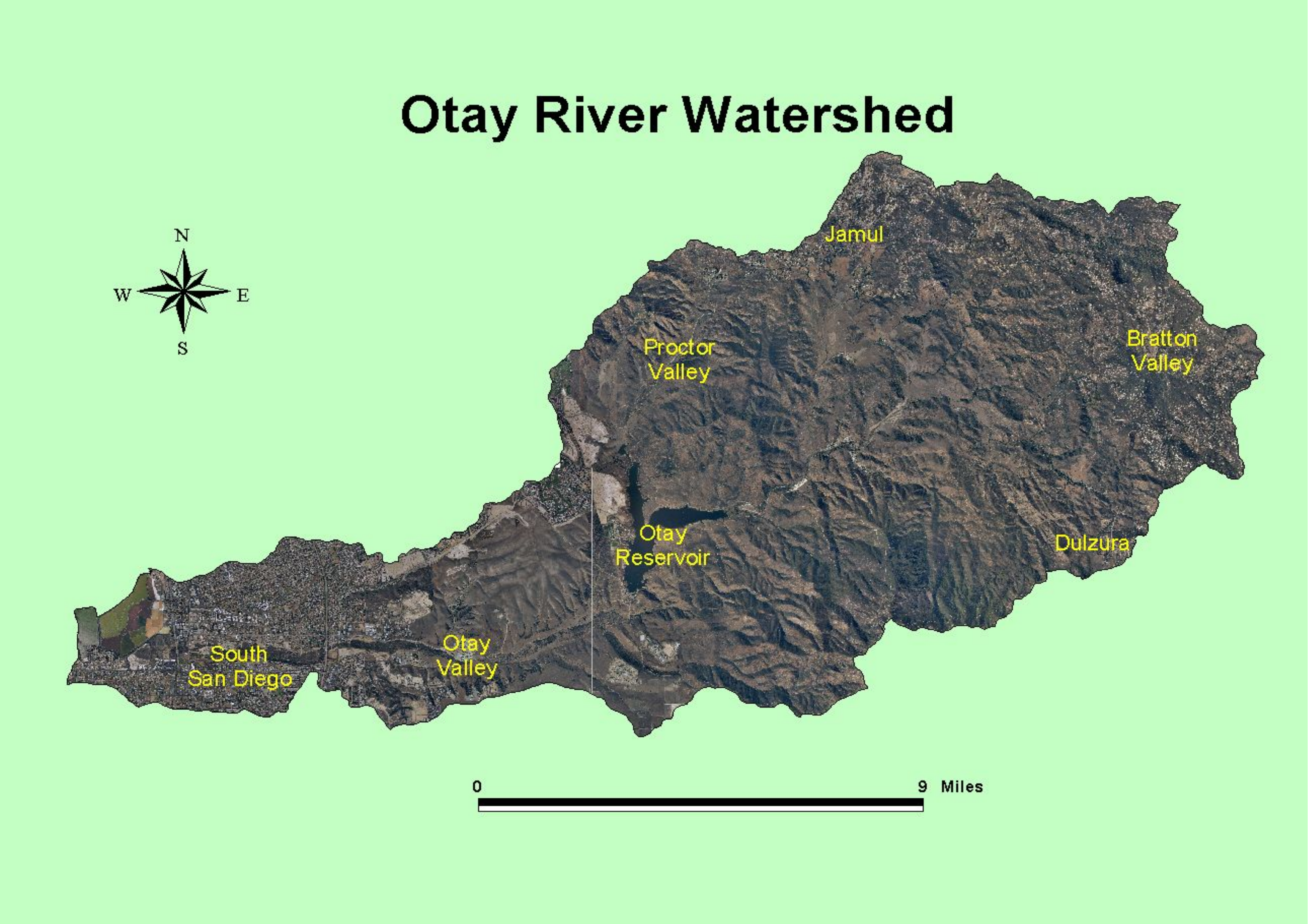

Figure 1. Otay River watershed study area

2.0 Objective

The primary objective of this project was to conduct a baseline assessment of riparian ecosystem integrity in the Otay River watershed under current conditions. Once completed, the information developed during the assessment can be used to evaluate the potential impacts of future development projects on riparian ecosystems in the Otay River watershed. Similar projects has been completed for the San Diego Creek and the San Juan / San Mateo River watersheds in Orange County (Smith 2000a, 2000b), as well as the San Jacinto and Santa Margarita watersheds in Riverside County (Smith 2003).

Three specific tasks were identified to meet the primary objective. The first was to conduct the baseline assessment of riparian ecosystem integrity in the watersheds under current conditions (i.e., baseline). This was accomplished by dividing the riparian ecosystems into assessment units or “riparian reaches” and assessing each riparian reach using a suite of indicators of riparian ecosystem integrity. Establishing baseline conditions allows for the subsequent comparison between riparian ecosystem integrity under current conditions and riparian ecosystem integrity under future alternative development scenarios. Such comparisons can help to guide the decision-making process concerning future development scenarios by ensuring avoidance, minimization, and adequate mitigation of impacts to riparian ecosystems, both individually and cumulatively.

The second task was to rank riparian reaches in terms of ecosystem integrity. Ranking was based on the ecosystem integrity indicator scores and hydrologic, water quality, and habitat integrity indices resulting from the baseline assessment. The rankings will be one of many factors used to evaluate various alternative development scenarios in the Otay River watershed.

The third task, to be completed in the future, will be to determine the impact of proposed alternative development scenarios on aquatic resources and riparian ecosystem integrity in the watershed. This is accomplished by comparing a variety of criteria under baseline conditions versus the “simulated" conditions that can be expected to occur as a result of implementation of a specific development scenario.

3.0 Background, Definitions, and Assumptions

3.1 Riparian Ecosystems

Riparian ecosystems are linear corridors of variable width that occur along perennial, intermittent, and ephemeral streams (Williams 1978). Perennial streams exhibit surface water flow in the channel throughout the year with low flow conditions a result of groundwater discharge to the stream channel. Intermittent streams exhibit surface water flow in the channel intermittently throughout the year, often with a seasonal pattern (i.e., winter and spring) with low flow conditions, when present, also a result of ground water discharge to the stream channel. Ephemeral streams exhibit surface water flow in the channel intermittently throughout the year. In the ephemeral stream surface water flow results from surface water runoff in response to precipitation events. Groundwater discharge does not contribute to surface water flow in the ephemeral stream channel.

Riparian ecosystems exhibit distinctive geomorphic features and vegetation communities in response to surface water flow in the stream channel, and the hydrologic interaction that occurs between the stream channel and adjacent areas during periodic exchanges of surface and ground water (Richards 1982; Harris 1987; Kovalchik and Chitwood 1990; Gregory et al. 1991; Malanson 1993; and Goodwin et al. 1997). The hydrologic interaction between streams and adjacent riparian areas typically results in two distinct areas, although either area may be narrow and seemingly absent under certain geologic or geomorphic conditions (Figure 2). The first area is the active floodplain which includes those portions of riparian ecosystem inundated by overbank flooding at a frequency of at least once every five years. This area exhibits the fluvial features associated with recurring flooding such as point bars, areas of scour, sediment

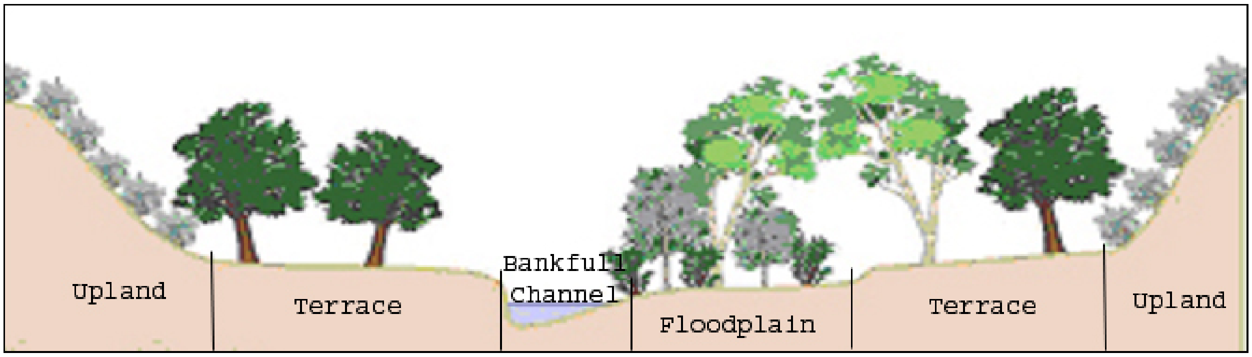

Figure 2. Generalized cross section of a riparian ecosystem

accumulation, natural levees, debris wrack, and vegetation communities that are either short lived or able to survive the effects of frequent flooding. The second area are terraces which consist of abandoned or historical floodplains formed by fluvial processes that took place under a historical, and often different, climatic conditions or hydrologic regimes (Knox et al. 1975; Graf et al. 1991; Rumsby and Macklin 1994). Under current climatic conditions and hydrologic regimes, the terraces are flooded less frequently, during larger magnitude events (Dunne and Leopold 1978). Vegetation communities on terraces are generally composed of woody perennials that require the higher water table present in the riparian zone, and are capable of surviving, or reestablishment, after floods.

For the purposes of this project, riparian ecosystems were defined from a functional perspective as perennial, intermittent, and ephemeral stream channels and the adjacent areas where the interaction with surface and groundwater results in distinctive geomorphic features and vegetation communities. Under natural conditions, the riparian ecosystem includes the bankfull stream channel, active floodplain, and less frequently flooded, historical floodplains/terraces.

3.2 Waters of the United States Versus Functional Riparian Ecosystems

Waters of the United States (WoUS) are the areas subject to regulation under Section 404 of the Clean Water Act (33 CFR Part 328.3). Wetlands are a subset of WoUS, and throughout this discussion, the term WoUS should be interpreted to include wetlands. Two categories of WoUS occur in association with southern California riparian ecosystems. The first category, non-wetland waters, includes the areas along perennial, intermittent, and ephemeral stream channels that exhibit a distinct bed and bank, but fail to meet one or more of the hydrologic, hydrophytic vegetation, and hydric soils criteria outlined in the Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory 1987). The second category of WoUS is wetlands, which are aquatic areas that meet all of the hydrologic, hydrophytic vegetation, and hydric soils criteria.

It is important to note that the “functional” riparian ecosystem, as defined above, has no special recognition, meaning, or status in the context of the Section 404 Regulatory Program. While functional riparian ecosystems normally include all WoUS regulated under the 404 Program and California Department of Fish and Game (CDFG) 1600 Program, riparian ecosystem may also includes areas that fall outside the jurisdiction of one or both of these programs. Consequently, a one-to-one spatial correspondence between riparian ecosystems and WoUS in the watershed may be absent. The lack of spatial correspondence is common in the arid and semi-arid southwestern United States where the active floodplain or historical terrace portion of the riparian ecosystem often meets one or two of the delineation criteria, but fails to meet all three delineation criteria necessary to qualify as a regulated wetland.

The spatial inconsistency between WoUS and riparian ecosystems is a result of the relatively generic hydrologic, hydrophytic vegetation, and hydric soil delineation criteria developed under the 404 Program for use in the wide variety of wetland types that occur in the United States. These generic delineation criteria necessarily ignore the unique way in which specific characteristics and processes contribute to the creation and maintenance of riparian as well as other functional wetland ecosystems. The intra- and inter-regional insensitivity of the generic delineation criteria is widely recognized, and while the need for regionalization of delineation criteria has been identified (Committee on Characterization of Wetlands 1995), no solution to this formidable task has been developed, much less implemented.

The spatial inconsistency is problematic in the context of the mandate to assess functions of WoUS as part of the 404 permit review process. An assessment cannot be accomplished by considering only the characteristics and processes of WoUS proper because the functions of WoUS are influenced by the characteristics and processes taking place in the riparian ecosystem, as well as those in the adjacent upland areas and the drainage basin of the riparian ecosystem (Kratz et al. 1991; Hornbeck and Swank 1992; Bedford 1996).

A solution for meeting this challenge was outlined as part of the Hydrogeomorphic (HGM) Approach (Smith et al. 1995). In the HGM Approach, characteristics and process occurring in the functional ecosystem, as well as the adjacent upland areas and the drainage basin are considered during the assessment process. However, when applying the results of the assessment in the context of the 404 permit review process, the results are applied to WoUS only. This project used a similar approach in that the influence of the riparian ecosystem, adjacent uplands, and drainage basin were considered in assessing riparian ecosystem integrity. Consequently, when applying the results of the assessment, consistency with policies and assumptions of the SAMP, the Section 404 permit review process, Endangered Species Act

Section 7 consultation, or the California Department of Fish and Game 1600 Program must be taken into account.

3.3 Riparian Ecosystem Integrity and Integrity Indices

Much has been written in the past about the concepts of ecological or ecosystem health and integrity (Rapport 1989; Costanza, Norton and Haskell 1991; Suter 1993; Scrimgeour and Wicklum 1996; Karr 1999). The two terms are often used interchangeably; however, the distinction made by Karr (1996) is instructive, and important in interpreting and applying the mandate of the Clean Water Act. Health refers to a flourishing condition, well-being, or vitality (Guralnik and Friend 1968). Integrity, on the other hand, refers to the quality, or state of being complete, and implies correspondence with a natural or original condition. Based on these distinctions, a cornfield, pine plantation, commercial nursery, and other culturally maintained ecosystem could be considered healthy, but not an ecosystem with high integrity. For this project, riparian ecosystems with high integrity were defined as those that support a balanced, diverse, and adaptive biological community resulting from natural evolutionary and biogeographic processes. In addition, high integrity riparian ecosystems exhibit the full range of physical, chemical, and biological attributes and processes that characterized riparian ecosystems in the region, over short and long term cycles, prior to cultural alteration.

The concept of ecosystem integrity is difficult to define because of its abstract nature. It is even more difficult to assess because of the wide variety of characteristics and processes across multiple spatial scales (i.e., riparian reach, local drainage, and drainage basin) that influence the integrity of riparian ecosystem. Consequently no single, direct measure of ecosystem integrity exists. For this project, three quantities of interest, or assessment “endpoints,” were selected to represent riparian ecosystem integrity (Leibowitz and Hyman 1999). They include hydrologic, water quality, and habitat integrity. The selection of these assessment endpoints follows directly from the mandate in Section 101(a) of the Clean Water Act to “…restore and maintain the chemical, physical, and biological integrity of the Nation’s waters”. The indices used to assess hydrology, water quality, and habitat integrity are defined and discussed in greater detail in Section 4.4.

3.4 Indicators For Assessing Hydrologic, Water Quality, and Habitat Integrity

In this procedure, indicators are the metrics used to assess the hydrologic, water quality, and habitat integrity of riparian ecosystems. Metrics can be divided into two categories, direct and indirect. “Direct metrics” are a quantitative direct measure of an assessment endpoint. For example, cubic feet per second, is a direct metric that measures the stream discharge endpoint. Direct metrics can be identified when the assessment endpoint is a narrowly defined and directly measurable. Direct metrics cannot be identified for broadly defined, abstract concepts like ecosystem integrity.

The second category of metric, the “indirect metric” is also referred to as “indicator”. Indicators are qualitative or quantitative measures related to an assessment endpoint in some way. Indicators are used to assess complex, or abstract endpoints for which no direct metric exists, or when direct metrics are too difficult or costly to assess. For example, tree basal area is an indirect metric, or indicator, for tree biomass. Many existing biological/ecological assessment methods use indicators. For example, the Habitat Evaluation Procedure (HEP) (USFWS 1980) has used habitat characteristics as indicators for more than 25 years to assess a “habitat suitability” endpoint in lieu of the more difficult and time consuming task of sampling animal populations directly (USFWS 1980). Indicators are used in a similar fashion in the Index of Biological Integrity (IBI) and related methods (Karr and Chu 1997), the instream flow incremental methodology (IFIM) (Bovee 1986), the Synoptic Approach (Leibowitz et al. 1992; Abbruzzese and Leibowitz 1997), and the Hydrogeomorphic (HGM) Approach (Smith et al. 1995).

Leibowitz and Hyman (1999) make an important distinction between “confirmed” and “judgment” indicators. Confirmed indicators are those in which the relationship between the indicator and endpoint can be described in a precise manner (i.e., mathematical) with a known level of statistical confidence. Judgment indicators, on the other hand, are those in which the relationship between the indicator and endpoint is less precisely defined. The relationship is typically based on trends or patterns from the literature, field observations, or professional judgment. Given adequate research, the assumed relationship between a judgment indicator and an endpoint can be confirmed. For example, it is possible to define a quantitative, mathematical relationship between land use and water quality in a watershed using numerical modeling methods (Hamlett et al. 1992). The use of confirmed versus judgment indicators represents a tradeoff in terms of the degree of certainty of the relationship between the indicator and endpoint, and the ability to obtain the information necessary to assess selected endpoints. Some authors have questioned the use of judgment indicators (Conroy and Noon 1996, Schumaker 1996). However, in real world situations the use of judgment indicators is often unavoidable given time and resource constraints, the lack of existing confirmed indictors, or the unavailability of quantitative data necessary to develop a confirmed indicator (Abbruzzese and Leibowitz 1997). Each of the indicators selected to assess hydrologic, water quality, and habitat integrity are discussed in greater detail in Section 4.3.

3.5 Reference Condition

In order to assess riparian ecosystem integrity, a standard of comparison or “reference condition” must be defined. The reference condition serves two purposes. First, it provides a concrete or virtual representation of the conditions, across multiple spatial scales, under which riparian ecosystems achieve and sustain a high level of integrity. Second, the reference condition provides a starting point from which to define and scale the relationship between the indicators and assessment endpoints.

Several different reference condition scenarios were suggested and considered for this project. Two of these were the “culturally unaltered” and “least culturally altered” reference condition. In southern California riparian ecosystems, the culturally unaltered reference condition implies conditions that existed prior to grazing, agriculture, fire suppression, water resource management, transportation corridors, urbanization, and other cultural alterations that can be identified. It is synonymous with what McCann (1999) referred to as pre-Columbian, meaning the conditions that existed prior to the influence of European explorers and subsequent immigrants. The least culturally altered reference condition refers to those conditions that currently exist in a watershed or region and most closely reflect culturally unaltered conditions.

Culturally unaltered was selected as reference condition for this project for several reasons. First, it represents the physical, chemical, and biological conditions under which riparian ecosystems have evolved naturally, and therefore, presumably represents the physical, chemical, and biological conditions that the Clean Water Act mandates should be maintained. While it can be argued that the culturally unaltered reference condition does not exist in southern California due to widespread existence of grazing, fire suppression, urban development, non-point air pollution, the disruption of historical metapopulation dynamics (Hastings and Harrison 1994), and a host of other factors, it is possible to make reasonable speculations as to what culturally unaltered conditions were like (Sedell and Luchessa 1981; Schubauer-Berigan 2000). It can also be argued that while it is impossible to restore culturally unaltered conditions, it may be feasible to restore some of the larger, isolated and remote areas to a condition that functionally approximates the culturally unaltered condition given adequate time and resources, and appropriate management.

In the restoration context, a reference condition based on the culturally unaltered scenario provides an appropriate target for restoring ecosystem integrity and function. On the other hand, a restoration target based on the least culturally altered reference condition provides an arbitrary, and often inappropriate target with the potential to "successfully" restore riparian ecosystems with low ecosystem integrity and function, and no natural corollary.

The second reason for selecting culturally unaltered as the reference condition is the advantage, both in terms of interpretation and comparability of results, of using the "absolute" standard of comparison culturally unaltered represents instead of the "relative" standard of comparison represented by the least culturally altered condition. To illustrate this advantage, consider the following scenario. Assessments of ecosystem integrity are performed on riparian ecosystems in two watersheds, one heavily urbanized, and the other occupying a wilderness area without roads. Two assessments are done in each watershed. The first assessment uses culturally unaltered conditions as the reference condition, and second uses least culturally altered conditions as the reference condition. Hydrology, water quality, and habitat integrity indices are generated for both assessments ranging from 1 to 10 with an index of 1 indicating low integrity. In the first assessment, using culturally unaltered conditions as the reference condition, the indices for the urban watershed are likely to be at the lower end of the index range, while the indices for the wilderness watershed are likely to be in the higher end of the index range. These results are intuitively reasonable, and in reality correct, because heavily urbanized watersheds have significantly less ecosystem integrity than wilderness area watersheds due to changes in land use, stream channelization, loss of habitat, and other factors.

Now consider the results for the second assessment using least culturally altered conditions as the reference condition. Indices for the urban watershed will be at the high end of the index range, because least culturally altered conditions, specific to the urban watershed, were used to scale indicators of ecosystem integrity. Indices for the wilderness watershed also will be at the high end of the index range for the same reason. However, these results are not intuitive because, using the foregoing definition of ecosystem integrity, the urban watershed in reality has a lower level of ecosystem integrity than the wilderness area, despite the fact that the indices of ecosystem integrity indicate there is little difference between the two. The non-intuitive nature of these results, and the inability to compare areas makes the use of the relative, least culturally altered reference condition, problematic.

The third reason for selecting culturally unaltered as the reference condition was the ability to define a culturally unaltered condition for the indicators of riparian ecosystem integrity without extensive reconnaissance in the watershed prior to conducting the assessment. For example, in the case of the indicators related to land use, it was reasonable to assume that under the culturally unaltered condition no grazing, agriculture, transportation, or urban development land uses existed. Similarly, in the case of the altered hydrologic conveyance indicator, it was reasonable to assume that under culturally unaltered conditions, stream channels were not straightened, lined, impounded, or piped and buried. The same could not be said for defining the least culturally altered condition. In order to define least culturally altered condition for assessment indicators it would be necessary to conduct reconnaissance in the watershed, prior to conducting the assessment, to determine the range of cultural alteration that existed and what represented least culturally altered condition.

It is often mistakenly assumed that since the reference condition used to scale indicators in the procedure is culturally unaltered conditions, the baseline assessment represents culturally unaltered conditions. Nothing could be further from the truth. The baseline assessment represents the condition of riparian ecosystems at the time of the assessment. The use of a culturally unaltered reference condition merely makes it possible to determine how far current conditions deflect from the reference condition. When determining the impact of future alternative development scenarios the comparison is made between baseline conditions and the expected post-development conditions. The impact ascribed to the alternative development scenario is the change in riparian ecosystem integrity between the baseline condition and the post-development condition, not reference condition.

4.0 Methods

4.1 Riparian Reach Assessment Units and Associated Areas

Due to the large geographic area covered by the project watershed, inherent variability of riparian ecosystems, and differential nature of historical impacts to riparian ecosystems in the watershed, the selection of an appropriate spatial unit for assessing riparian ecosystem integrity was critical. The assessment unit selected for this project was called the riparian reach (RR), defined as a segment of a main stem bankfull stream channel and adjacent riparian ecosystem that was relatively homogenous in terms of its geological, geomorphological, edaphic, hydrological, channel morphological, vegetation, and cultural alteration characteristics (Olson and Harris 1997.

In association with each riparian reach, the following other entities were identified: “local drainage”, “main stem channel”, “main stem tributary channels”, and “drainage basin”. The local drainage of a riparian reach includes the area from which surface water drains directly to the main stem channel, or tributaries that enter the main stem channel, of the riparian reach. The main stem channel is the primary channel in the local drainage, and main stem tributaries are stream channels that originate in the local drainage of the riparian reach and flow directly to the main stem channel.

Figure 3 provides an illustration of the riparian reach, local drainage, main stem channel, and main stem tributary channels for riparian reach “BM-05”. In this figure the local drainage boundary of BM-05 is shown as a thick brown line, and the local drainage boundaries of adjacent riparian reaches are shown as thin brown lines. The mains stem is the thick blue line running from the upstream end of the local drainage to the downstream end of the local drainage, and tributaries are the dotted blue lines within the local drainage boundary. The riparian reach (i.e., the actual unit of assessment) is the green shaded area labeled riparian ecosystem, which includes the area adjacent to the main stem channel within the confines of the local drainage boundary.

The drainage basin of a riparian reach includes the local drainage of the riparian reach as well as the local drainage of all upstream riparian reaches. Figure 4 illustrates the local drainage of riparian reach BM-05. This is the dark green stippled area, which includes the local drainage of BM-05, as well as the local drainage of upstream riparian reaches BM-06 and BM-07.

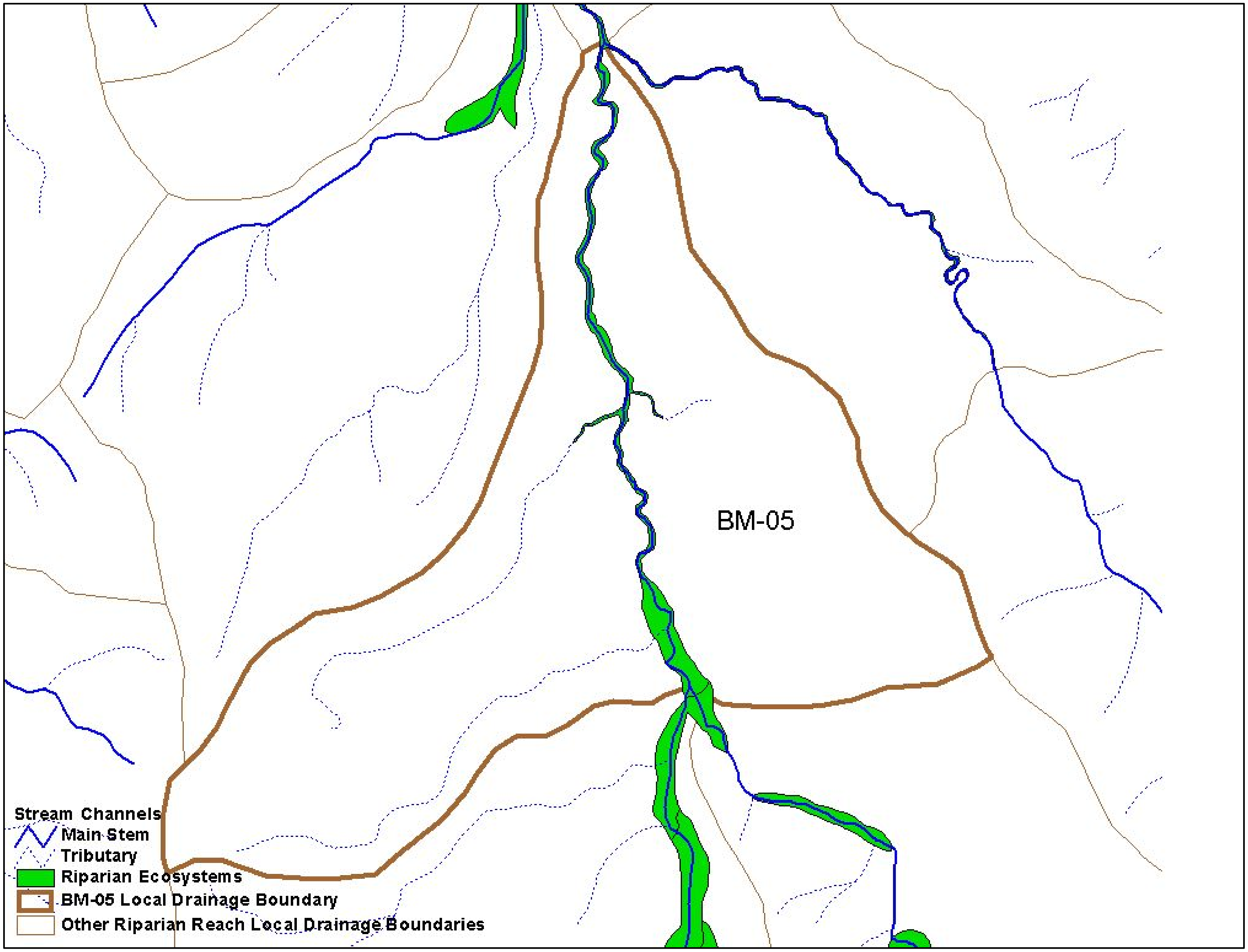

Figure 3. Example riparian reach and its associated local drainage

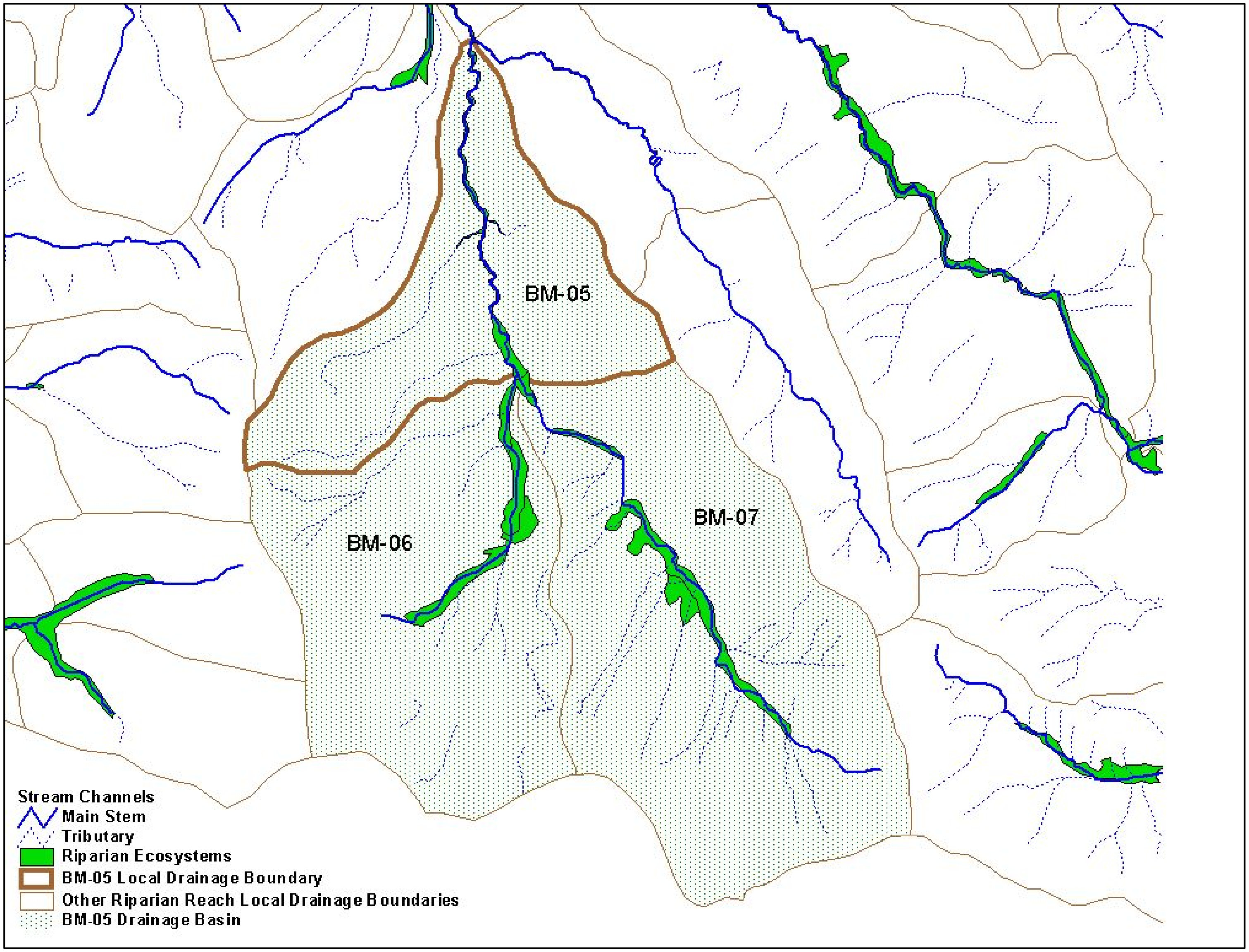

Figure 4. Example riparian reach and its associated local drainage and drainage basin

Figure 4 also illustrates the distinction between “headwater” and “non-headwater” riparian reaches. Headwater riparian reaches are those that do not have other riparian reaches upstream, while non-headwater reaches do have other riparian reaches upstream. In Figure 4, BM-06 and BM-07 are headwater riparian reaches, and BM-05 is a non-headwater riparian reach.

Preliminary maps of riparian reach, local drainage, and drainage basin boundaries and main stems in each riparian reach were developed as ArcView themes (see Appendix 1) on the basis of initial field reconnaissance, aerial photos, topographic maps (i.e., a digital raster graphic), and the WoUS maps developed by Lichvar and Ericsson (2003).

Each riparian reach was assigned pneumonic identifier for display and digital manipulation purposes. The local drainage of a riparian reach was combined with the local drainages of all upstream riparian reaches to define the drainage basin boundary of each riparian reach. On non-headwater riparian reaches (i.e., riparian reaches with other riparian reaches upstream) the longitudinal (i.e., upstream/downstream) boundaries of a riparian reach corresponded to changes in stream gradient or channel morphology resulting from geological control (e.g. knick points), tributaries/distributaries, artificial grade control structures, or other features related to cultural alteration. On headwater reaches, the upstream end of main stem channel of headwater riparian reach always included third order streams (Strahler 1952, 1957) as mapped by Lichvar and Ericsson (2003), and in many cases the upstream end included second order streams. Strahler stream order refers to a stream numbering method in which the smallest, terminal stream segments receive a designation of first order or “1” (Figure 5). A stream segment downstream from the confluence of two first order stream segments receives a designation of second order or “2”. A stream segment downstream from the confluence of two second order stream segments receives a designation of third order or “3”, and so on. In all cases, stream order increases only when two stream segments of equal order join.

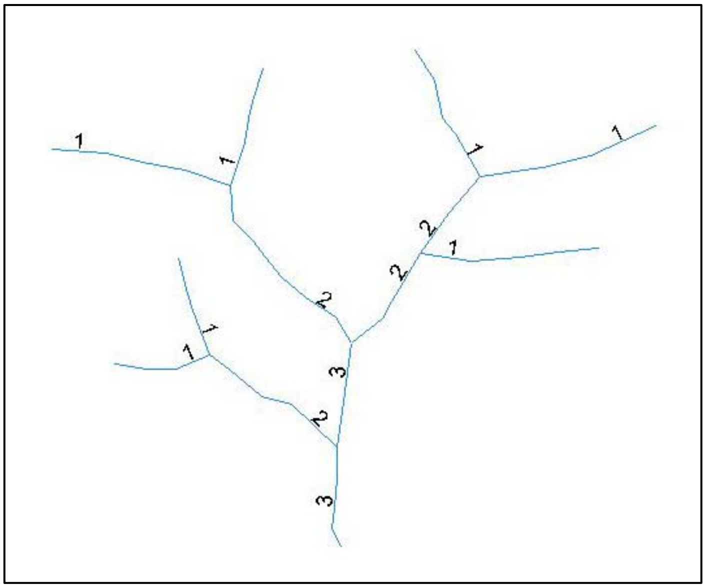

Figure 5. Example of Strahler stream orders

The factors that determined the upstream extent of the riparian reach were stream density, accessibility, and the extent of a riparian vegetation component. Lateral boundaries of riparian reaches corresponded to either an estimate of the 100-year flood elevation contour, the extent of identifiable historic alluvial terraces, or the base of valley wall or artificial structure. In all cases the riparian reach included the bankfull channel, Zone 1, Zone 2 (see Section 3.1 and Figure 2).

4.2 Characterization and Assessment of Riparian Reach Assessment Units

Characterization of riparian reaches was accomplished during a site visit to each reach. The general strategy during a site visit was to begin at the downstream end of the riparian reach and conduct a walking reconnaissance of the main stem channel through the riparian reach. On longer reaches we drove to representative sections of the riparian reach and conduct separate walking reconnaissance. On headwater reaches the walking reconnaissance included at least the lower one-third of the main stem channel of the riparian reach. Time constraints precluded conducting a walking reconnaissance of the entire main stem channel of headwater reaches in roadless areas. In these situations, field observations were supplemented with interpretations based on aerial photographs.

After reconnaissance through a riparian reach, a decision was made to either retain the preliminary riparian reach boundaries, or to further divide the riparian reach into two or more riparian reaches. Based on the observations made during reconnaissance, a representative portion of the riparian reach was selected and a riparian reach characterization data sheet was completed. The characterization included notes on the species and location of the dominant vegetation in terms of geomorphic features (i.e., bankfull channel, floodplain, terrace), measurement of channel characteristics, general field notes about the nature of the riparian reach, and indicator values for those integrity indicators measured in the field.

Riparian reaches were characterized, and indicators were assessed during the field site visit and later using spatial analysis in ArcView. Table 1 provides a listing of the information collected as part of riparian reach characterization and assignment of metric values to indicators. The second column in Table 1 indicates the method by which indicators were assessed. Based on field observation and/or spatial analysis, each indicator was assigned a value representing the percent deviation of the indicator from the reference condition in that reach. For example, if the main stem of a riparian reach was completely channelized, an indicator value of 100 was

Table 1. List of data for characterizing riparian reaches and indicators

Description	Method
Riparian Reach ID	Field
Drainage Basin	Field
USGS 7.5 Minute Topographic Quad	GIS
Main stem Downstream End Coordinates (UTM)	GIS
Main stem Upstream End Coordinates (UTM)	GIS
Size of Mapped Riparian Ecosystem in Riparian Reach Local Drainage (ha)	GIS
Size of Mapped Riparian Ecosystem in Riparian Reach Drainage Basin (ha)	GIS
Size of Riparian Reach Local Drainage (LD) (ha)	GIS
Length of Local Drainage Perimeter (m)	GIS
Size of Riparian Reach Drainage Basin (DB) Area (ha)	GIS
Valley Type (Rosgen)	Field
Valley Length (m)	Field / GIS
Valley Width (m)	Field / GIS
Main stem Downstream End Elevation (m)	GIS
Main stem Upstream End Elevation (m)	GIS
Valley Slope (%) (Estimated From 7.5 Minute Topo)	Calculated
Engineered Channel Type or Rosgen Stream Type	Field
Main stem Channel Length in (m) (Smith)	GIS
Main stem Channel Length in DB (m) (Smith)	GIS
Main stem and Tributary Channel Length in Local Drainage (m) (Lichvar)	GIS
Main stem and Tributary Channel Length in Drainage Basin (m) (Lichvar)	GIS
Main stem Channel Length / Main stem Channel and Tributary Channels Length	Calculated
Drainage Density	Calculated
Channel Slope	Calculated
Sinuosity	Calculated
Bankfull Width (ft)	Field
Bankfull Width (m)	Calculated
Floodprone Width (ft)	Field
Floodprone Width (m)	Calculated
Bankfull Maximum Depth (in)	Field
Bankfull Maximum Depth (cm)	Calculated
Bankfull Mean Depth (in)	Field
Bankfull Mean Depth (cm)	Calculated
Bankfull Cross-Sectional Area (m^2)	Calculated
Width / Depth Ratio	Calculated
Entrenchment Ratio	Calculated
Natural Channel Substrate Bedrock / Boulder (%)	Field
Natural Channel Substrate Cobble (%)	Field
Natural Channel Substrate Gravel (%)	Field
Natural Channel Substrate Sand (%)	Field
Natural Channel Substrate Silt / Clay (%)	Field

Table 1 cont.

Description	Method
Indicator 1 % of Main Stem with Improved Hydraulic Conveyance	Field
Indicator 2 % of Blueline Tributaries with Improved Hydraulic Conveyance	Field
Indicator 3 % of Main Stems in DB with Improved Hydraulic Conveyance	Field/GIS
Indicator 4 % of Main Stem with Perennialized Stream Flow	Field
Indicator 5 % of Main Stems in DB with Perennialized Stream Flow	Field/GIS
Indicator 6 % of Main Stem lacking Floodplain Interaction	Field
Indicator 7 % of Main Stem Channel with Surface Water Retention	Field/GIS
Indicator 8 % of Drainage Basin with Surface Water Retention	Field/GIS
Indicator 9 % of Main Stem with Surface Water Imported, Exported or Diverted	Field/GIS
Indicator 10 % of DB with Surface Water Imported, Exported or Diverted	Field/GIS
Indicator 11 Imperviousness Index	GIS
Indicator 12 Sediment Regime Condition Index	Field
Indicator 13 Exotic Plant Species Index	Field
Indicator 14 Riparian Vegetation Condition Index - Floodplain	Field
Indicator 15 Riparian Vegetation Condition Index - Terrace	Field
Indicator 16 % Main Stem Corridor Breaks in Riparian Reach	Field/GIS
Indicator 17 % Main Stem Corridor Breaks in Drainage Basin	Field/GIS
Indicator 18 % Cultural Alteration in a 300' Buffer	Field/GIS
Indicator 19 % of Land Use Land Cover (LULC) Contributing to Nutrient Increase	GIS
Indicator 20 % of LULC Contributing to Pesticide Increase	GIS
Indicator 21 % of LULC Contributing to Hydrocarbon Increase	GIS
Indicator 22% of LULC Contributing to a Sediment Increase	GIS
Indicator 23 % of LULC Contributing to Nutrient Increase	GIS
Indicator 24 % of LULC Contributing to Pesticide Increase	GIS
Indicator 25 % of LULC Contributing to Hydrocarbon Increase	GIS
Indicator 26% of LULC Contributing to a Sediment Increase	GIS
Indicator 27 % of Suitable Wildlife Habitat in Local Drainage	GIS

assigned to the Improved Hydraulic Conveyance – Riparian Reach indicator. The assignment of values to indicators was based on an assumed, relative, categorical relationship defined between indicators and assessment endpoints. The assumption was that an increase in the deviation from the reference condition represented an equivalent decrease in the level of riparian ecosystem integrity in terms of the specific indicator. For example, in comparing two riparian reaches in terms of the land use/land cover indicator, the riparian reach with the larger percentage of urban land use/land cover in the drainage basin would be assumed to have lower integrity, at least in terms of the contribution of the indicator to endpoint integrity. This approach to scaling indicators to reference condition, and by implication to endpoint integrity, was possible because how indicators were defined (i.e., always measurable as a percent deviation from reference condition), and based on information from published studies, field data and observations, and professional judgment as outlined the Assessment Endpoints and Assessment Indicators sections above.

A number of areas on private lands within the Otay River watershed were not visited because the County of San Diego was unable to acquire permission from landowners to access the property (Figure 6). In these areas, riparian reaches could not be divided into the normal assessment units representing..."relatively homogenous areas in terms of its geological, geomorphological, edaphic, hydrological, channel morphological, vegetation, and cultural alteration characteristics." Consequently, in these areas, the riparian reaches designated were longer than normal, and often encompassed more heterogeneous riparian ecosystems than normal. In these reaches, the characterization and assignment of metric values to indictors was

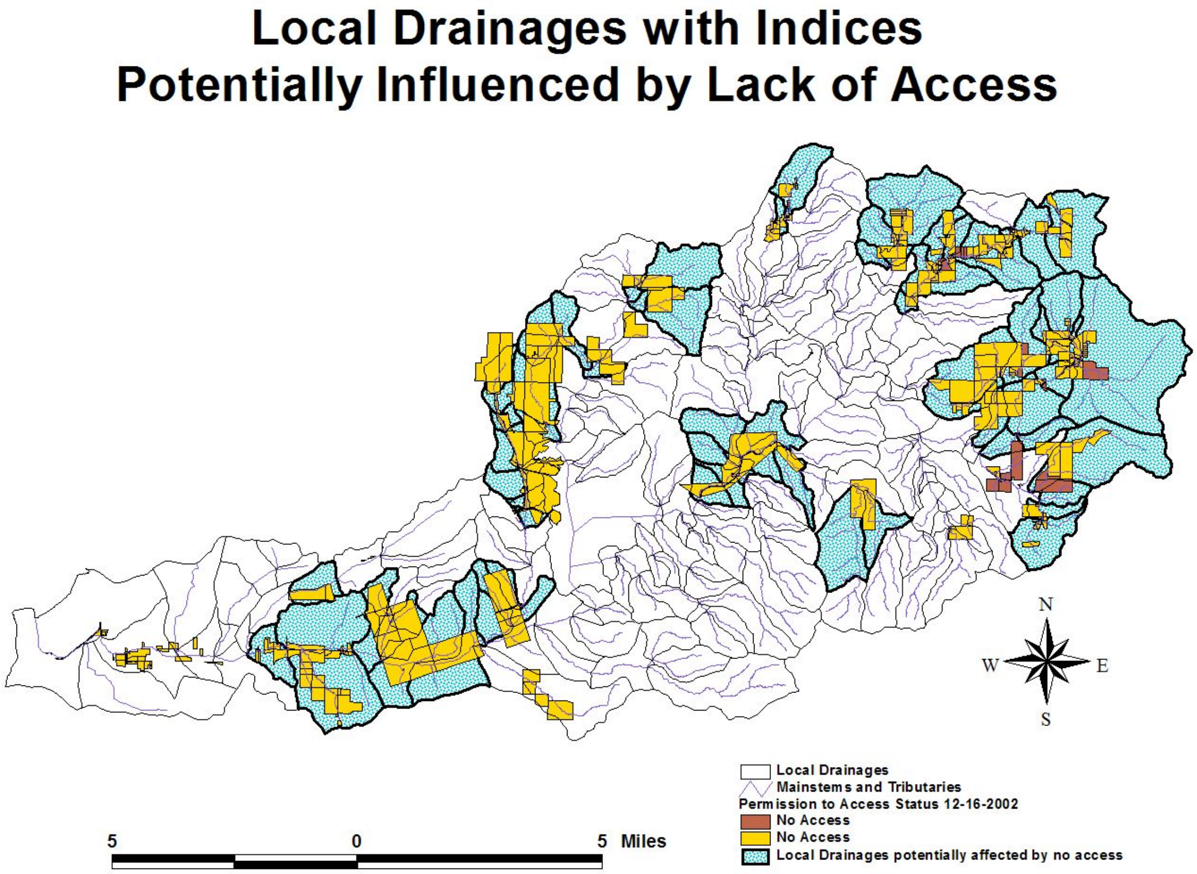
Local Drainages with Indices Potentially Influenced by Lack of Access

Figure 6. Local drainages with indices potentially influenced by lack of access

completed using aerial photographs, topographic maps, and information from nearby and similar riparian reaches. The inability to designate appropriate riparian reaches or conduct field sampling had significant implications with respect to the validity of integrity indices calculated for these reaches.

4.3 Assessment Indicators

The objective in selecting assessment indicators was to capture, to the greatest degree possible, the full range of characteristics and processes that influence hydrologic, water quality, and habitat integrity of riparian ecosystems at the riparian reach, adjacent upland, and drainage basin scale. Potential indicators were gleaned from a review of existing assessment methods (Dinius 1987; Lee et al. 1997; Ladson et al. 1999). Further investigation of the literature on riparian ecosystems, field observations, and the collective experience of individuals participating in the project provided additional potential indicators.

Several factors influenced the final selection of assessment indicators. First, was the need to match the project objectives of establishing baseline conditions and the ability to make comparisons between riparian ecosystems with available data, time and resources. Other factors included the large project area (>450 km^2), a short time frame and limited budget, insufficient quantitative data at the riparian reach assessment unit scale, and the lack of existing confirmed indicators. Another factor was the requirement to develop an open and easily understood approach that would allow participation and input from multiple stakeholders representing a range of perspectives from the development community and federal and state agencies charged with the protection of sensitive, threatened, and endangered species. Ultimately, a balancing of all these factors led to the selection of the indicators described below.

Each of the indicators selected are defined in the following sections and discussed in terms of the relationship between the indicator and relevant integrity indices (see Section 3.3). In addition, the method used to measure the indicator and assign an indicator value is described, along with the reference condition and range of indicator values used to assign indicator scores. Throughout this section the subscripts following the indicator acronym designates the spatial scale at which the indicator is applied with “RR” indicating the riparian reach, “RRT” indicating major tributaries mapped as blue lines on United States Geological Survey (USGS) 7.5 minute topographic maps that drain directly to the riparian reach, "F" indicating floodprone area or floodplain of the riparian reach, "T" indicating terraces of the riparian reach, “LD” indicating the local drainage of the riparian reach, and “DB” indicating the drainage basin of the riparian reach.

4.3.1 Improved Hydraulic Conveyance (IHC_{RR} / IHC_{RRT} / IHC_{DB})

Improved Hydraulic Conveyance indicates the degree to which engineering techniques have been used to “improve” the capacity of channels to convey surface water downstream. The engineering techniques involve reducing the frictional resistance (i.e., roughness) caused by channel substrate, vegetation, woody debris, and other objects in the channel (Barnes 1967), minimizing the wetted perimeter, and/or shortening the length of a channel. Specific techniques include dredging, straightening, hardening/lining of the stream channel, and the removal of vegetation (Galay 1983, Brookes 1988).

Increasing the volume of water and velocity at which water is conveyed downstream can result in a significant change in the hydrologic regime, and hence hydrologic integrity, in the riparian reach where the alteration occurs as well as in upstream and downstream reaches. For example, removal of vegetation decreases channel stability and increases erosion by reducing the resistance afforded by the network of plant roots, and by increasing the velocity and consequently the erosive force of water in the channel. A straightened stream reach will typically respond by incising to reestablish a more energy efficient and stable channel slope (Shankman and Samson 1991). This in turn initiates headcutting and increased erosion upstream. Downstream of an altered stream channel the hydrologic regime can also be affected in terms of increased peak discharges, a decrease in channel stability, and an increase in erosion due to increased water velocity.

This indicator was measured as the percent of the main stem channel through the riparian reach with improved hydraulic conveyance. At the riparian reach and riparian reach tributary scale, aerial photography and field observations were used to estimate the value of the metric. At the drainage basin scale, the indicator was calculated as the weighted average of the percent of Improved Hydraulic Conveyance for all riparian reaches in the drainage basin of the riparian reach using the following formula:

$$\sum_{i=1}^{i_n}\left[IHC_{RR} * \left({ML_{RR}} / {ML_{DB}} \right)\right] \tag{1}$$

Where: IHC_{RR} = % of main stem in a riparian reach with Improved Hydraulic Conveyance
ML_{RR} = Length of main stem channel in a riparian reach
ML_{DB} = Length of main stem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the main stem channel in riparian reach, or major tributaries to the riparian reach, with Improved Hydraulic Conveyance. Indicator scores were assigned based on range of indicator values in Table 2.

Table 2. Range of indicator values for scaling the Improved Hydraulic Conveyance indicator

Indicator Value Range	Score
≤5% of riparian reach main stem/drainage basin with IHC	5
>5 and ≤15% of riparian reach main stem/drainage basin with IHC	4
>15 and ≤30% of riparian reach main stem/drainage basin with IHC	3
>30 and ≤50% of riparian reach main stem/drainage basin with IHC	2
>50% of riparian reach main stem/drainage basin with IHC	1

4.3.2 Perennialized Stream Flow (PSF_{RR} / PSF_{DB})

Perennialized Stream Flow indicates the degree to which the hydrologic regime of a riparian reach has been altered by a supplementary supply of surface water resulting from cultural activities such as irrigation. Perennialization refers to the conversion of intermittent or ephemeral stream channels to a perennial stream through the addition of surface water flow (usually at low levels) in a stream channel from artificial supplies of surface water. The supply of water usually occurs in the form of irrigation or treated return water. In arid and semi-arid regions, perennialization facilitates a shift in plant and animal community composition away from what normally occurs in a riparian reach that is not perennialized. Perennialization also has the potential to affect physical and chemical processes in riparian ecosystems.

This indicator was measured as the percent of the main stem channel through a riparian reach that exhibited perennialized stream flow due to supplementary sources of water at the time of the field visits, or showed evidence of perennialized stream flow (i.e., occurrence of *Typha* sp., *Carex* sp. and/or other emergent aquatic species). Field observations and aerial photographs were used to assign a value to the indicator. The evidence used to identify a stream as perennialized was the presence of low flow during dry periods. Other types of evidence included nutrient enrichment based on the presence of blue-green algae and vascular species such as *Typha* sp., outfall pipes and other inlet structures entering a reach, residential developments and golf courses in the drainage basin, interbasin transfer import points, and the lack of evidence of a natural source of low flow.

At the drainage basin scale, the indicator was calculated as the weighted average of the percent of Perennialized Stream Flow for all riparian reaches in the drainage basin of the riparian reach using the following formula:

$$\sum_{i=1}^{i_n}\left[PSF_{RR}*\left({ML_{RR}}\big/{ML_{DB}}\right)\right] \tag{2}$$

Where: PSF_{RR} = % of main stem in a riparian reach with Perennialized Stream Flow
ML_{RR} = Length of main stem channel in a riparian reach
ML_{DB} = Length of main stem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the main stem channel of a riparian reach with perennialized stream flow. Indicator scores were assigned based on the range of indicator values in Table 3.

Table 3. Range of indicator values for scaling the Perennialized Stream Flow indicator

Indicator Value Range	Score
≤5% of stream channel exhibiting perennialized flow	5
>5 and ≤15% of stream channel exhibiting perennialized flow	4
>15 and ≤30% of stream channel exhibiting perennialized flow	3
>30 and ≤50% of stream channel exhibiting perennialized flow	2
>50% of stream channel exhibiting perennialized flow	1

4.3.3 Floodplain Interaction (FI_{RR})

Floodplain Interaction indicates of the degree to which the overbank hydrologic connection between the bankfull channel and the active floodplain and terraces of the riparian ecosystem has been lost in a riparian reach. The lost connection could be a result of levees, channelization, or channel incision. Many of the characteristics and processes of riparian ecosystems are dependent on periodic hydrologic interaction between the stream channel and the floodplain. When the hydrologic connection is lost, the physical and biological characteristics of the riparian ecosystem change, regardless of the reason.

This indicator was measured as the percent of the main stem channel through a riparian reach that was physically disconnected from the floodplain as a result of culturally accelerated channel erosion/incision, channel improvements, or levees. An incised main stem channel in which the active floodplain has been reestablished within the incised channel through normal fluvial processes was not considered disconnected (Keller 1972). When one side of the channel was disconnected from the floodplain, 50% of the stream channel was considered disconnected from the floodplain and terraces. When both sides of the channel were disconnected from the floodplain, 100% of the stream channel was considered disconnected. Aerial photography and field observations were used to estimate the value of the metric.

The reference condition was defined as <5% of the main stem stream channel disconnected from the floodplain. Indicator scores were assigned based on the range of indicator values in Table 4.

Table 4. Range of indicator values for scaling the Floodplain Interaction indicator

Indicator Value Range	Score
≤5% of main stem stream channel disconnected from the floodplain	5
>5 and ≤15% of main stem stream channel disconnected from the floodplain	4
>15 and ≤30% of main stem stream channel disconnected from the floodplain	3
>30 and ≤50% of main stem stream channel disconnected from the floodplain	2
>50% of main stem stream channel disconnected from the floodplain	1

4.3.4 Surface Water Retention (SWR_{RR} / SWR_{DB})

Surface Water Retention indicates the degree to which the hydrologic regime in a riparian reach has been altered as a result of short and long-term storage of surface water in reservoirs, lakes, sediment basins, retention ponds, and similar surface water storage facilities. Streams in arid and semi-arid regions are disturbance-dominated systems (Resh et al. 1988; Power et al. 1988, 1996; Rood and Mahoney 1990). During flash floods, stream discharge can increase by several orders of magnitude causing aquatic organism mortality, destruction of riparian vegetation, and changes in channel morphology. The biological components of riparian ecosystems have adapted to these episodic cycles of disturbance, and developed a variety of mechanisms that make it possible to survive and indeed flourish where other organisms cannot. Short and long-term retention of surface water in storage facilities can significantly alter the characteristic pattern of discharge over the water year (Cushman 1985; Bain et al. 1988; Dynesius and Nilsson 1994; Ligon et al. 1995; Poff et al. 1997; Hadley and Emmett 1998). Most importantly, it eliminates the low frequency, high volume discharges that reset the system (Hawkins et al. 1997). However, it can also lead to perennialization of streamflow, change the pattern of seed distribution, germination, and survival, and change a variety of other physical and biological processes necessary to perpetuate the riparian ecosystem (Hynes 1975; Warren 1979; Lotspeich and Platts 1982; Frissell et al.1986; Kondolf et al.1987; Debano and Schmidt 1989; Stromberg and Patton 1991; Johnson 1994; Power et al. 1996; Kershner 1997; Kondolf 1997; Richter et al. 1997).

This indicator was measured as the percent of the riparian reach upstream of lakes, reservoirs, dry dams, sediment basins, retention ponds, or similar facilities capable of storing surface water from several weeks to months. At the drainage basin scale, the indicator was calculated as the weighted average of the percent of Surface Water Retention for all riparian reaches in the drainage basin of the riparian reach using the following formula:

$$\sum_{i=1}^{i_n}\left[SWR_{RR} * \left({ML_{RR}} \middle/ {ML_{DB}} \right)\right] \tag{3}$$

Where: SWR_{RR} = % of main stem in a riparian reach with Surface Water Retention
ML_{RR} = Length of main stem channel in a riparian reach
ML_{DB} = Length of main stem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the drainage basin of a riparian reach upstream of a lake, reservoir, dry dam, sediment basin, retention pond, or similar facility capable of storing surface water from several days to months. Indicator scores were assigned based on the range of indicator values in Table 5.

Table 5. Ranges of indicator values for scaling the Surface Water Retention indicator

Indicator Value Range	Score
≤5% of drainage basin drains to surface water storage facilities	5
>5 and ≤15% of drainage basin drains to surface water storage facilities	4
>15 and ≤30% of drainage basin drains to surface water storage facilities	3
>30 and ≤50% of drainage basin drains to surface water storage facilities	2
>50% of drainage basin drains to surface water storage facilities	1

4.3.5 Import, Export, or Diversion of Surface Water (IED_{RR})

Import, Export, or Diversion of Surface Water indicates the degree to which the hydrologic regime of a riparian reach has been altered as a result of import, export, or diversion of surface water. Inter-basin import and export of surface water, and the intra-basin diversion of water for public water supply, irrigation, and ground water recharge is common in the arid western United States. The import, export, or diversion of water within and between watersheds has been shown to affect a wide variety of biotic and abiotic processes as a result of changes in the quantity and timing of surface water discharge and other aspects of the hydrologic regime (Taylor 1982; Kondolf et al. 1987; Stromberg and Patten 1990; Petts 1996; Davies, Thoms, and Meador 1992)

In the Otay watershed for example, the hydrologic regime in riparian reaches along Dulzura Creek are significantly altered an inter-basin transfer of water entering in the vicinity of Dulzura, and the hydrologic regime in riparian reaches along the lower Otay are altered by the Otay Reservoir.

At the reach scale, the indicator was assigned a value of 0% if the hydrologic regime was not significantly altered by upstream import, export, or diversion of water, or assigned an indicator value of 100% if the hydrologic regime was significantly altered. The assignment was based on multiple field observations at different times of the year whenever possible.

At the drainage basin scale, the indicator was calculated as the weighted average of the IED_{RR} indicator value for all riparian reaches in the drainage basin of the riparian reach using the following formula:

$$\sum_{i=1}^{i_n}\left[IED_{RR} * \left({ML_{RR}}\big/{ML_{DB}} \right)\right] \tag{4}$$

Where: IED_{RR} = 0% if hydrologic regime not altered, and 100% if hydrologic regime altered by the import, export, or diversion of surface water
ML_{RR} = Length of main stem channel in a riparian reach
ML_{DB} = Length of main stem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the riparian reach with a hydrologic regimes significantly altered by the import, export, or diversion of surface water. Indicator scores were assigned based on the range of indicator values in Table 6.

Table 6. Range of indicator values for scaling the Import, Export, or Diversion of Water indicator

Indicator Value Range	Score
≤5% of riparian reach altered by import, export, or diversion of water	5
>5 and ≤15% of riparian reach altered by import, export, or diversion of water	4
>15 and ≤30% of riparian reach altered by import, export, or diversion of water	3
>30 and ≤50% of riparian reach altered by import, export, or diversion of water	2
>50% of riparian reach altered by import, export, or diversion of water	1

4.3.6 Imperviousness and Reduced Infiltration Capacity (IMP_{LD})

Imperviousness surfaces (i.e., roads, rooftops, parking lots) have been shown to be related to increases in surface water runoff and the reduction of the quality of surface water runoff (Benke et al. 1981, Booth 1991, Evett 1994, Klein 1979). Urbanization is the primary cause of increases in the amount of impervious surfaces. Activities that compact or alter the soil surface, porosity, or vegetation cover, reduce the infiltration capacity of the soil and increase the amount of surface water that runs off. Vehicular traffic, grazing, and intensive recreational are the primary causes of reduce soil infiltration. Exposure of the soil to direct raindrop impact by removal of vegetation diminishes the openness of the soil surface and reduces infiltration. In the western United States specifically, livestock grazing, agriculture, and urbanization have often been identified as contributors to increased surface water runoff and non-point sources of sediment, nutrients, and other classes of pollutants (Armour et al. 1991; Sedgwick and Knopf 1991; Charbonneau and Kondolf 1993; Bush and Smith 1995; Rothrock et al. 1998). Heavily grazed areas can reduce infiltration rates by more than half (Berglund et al. 1981).

The effects of impervious and compacted surfaces are not limited to the tract of land where the change actually takes place. Indirect effects often occur in stream, aquatic resources, and riparian systems that occur down gradient from the altered tract of land (Ryan 1991). This is, of course, a result of the fact that water and accumulated or eroded materials move down gradient (i.e. downhill and downstream) in response to gravitational forces. The relationship between changes in Land Use Land Cover (LULC) and the quantity and quality of surface water has been documented for a variety of wetland and aquatic systems in the United States (Brugham 1978; Ehrenfield 1983; Kuenzler 1986; Howarth et al. 1991; Richards and Host 1994; Cooper 1995; Blair 1996; Wilber et al. 1996; Caruso and Ward 1998).

An index of imperviousness and reduced infiltration capacity was developed to capture the degree to which changes in LULC affect hydrologic and water quality integrity in downstream riparian ecosystems. This indicator was assigned a score by matching existing land use in the local drainage of a riparian reach to the descriptions in Table 7. The reference condition was defined as a LULC of primarily native vegetation.

Table 7. Description of conditions for assigning the Imperviousness and Reduced Infiltration Capacity indicator score

Description of Conditions	Score
Primarily Native Vegetation	5
Grazing Land / Native Vegetation Mix	4
Primarily Grazing Lands or Agriculture	3
Primarily Residential OR Residential / Grazing Land / Agricultural Mix	2
Primarily Industrial OR Commercial OR Industrial / Commercial / Residential Mix	1

4.3.7 Sediment Regime (SR_{RR})

Sediment Regime indicates the degree to which the sediment dynamics in the main stem channel of a riparian reach are in equilibrium with respect to the supply of sediments from upstream sources and erosion and deposition processes within the channel. A variety of cultural activities can alter sediment dynamics and/or channel geometry. These types of changes include channel erosion due to physical disturbance, channel incision and head-cutting due to the alteration of slope, channel aggregation due structures that impede flow (i.e., weirs, drop structures, culverts), and irrigation diversions (Kondolf et al. 1987).

This indicator was assigned a score by matching field observations to the descriptions in Table 8. The reference condition was defined as exhibiting a sediment regime in equilibrium with respect to supply, erosion, and deposition processes, and not affected by cultural alteration.

4.3.8 Exotic Plant Species (EXO_{RR})

Exotic Plant Species indicates the degree to which exotic plants have displaced the native plant community along the main stem channel, floodplain, and terraces of a riparian reach. The presence of exotic species has the potential to affect hydrologic, water quality, and habitat integrity of riparian ecosystems. Once established, exotic plant species often have an advantage over native species because the diseases, predators, or competitors that control the species in their native locality are absent (Bohn and Amundsen 2001). This can lead to the rapid and extensive spread of exotics which has been documented for a number of species that invade southern California riparian areas (e.g., *Arundo donax* (Bell 1997, Frandsen and Jackson 1993), *Tamarix* spp. (Sher, Marshall and Gilbert 2000), and numerous forbs and grasses (D'Antonio and Vitousek 1992). Once established, exotic plant species have an indirect affect on hydrologic, water quality, and habitat integrity. For example, animal species that rely on native plant species

Table 8. Description of conditions for assigning Sediment Regime indicator score

Description of Conditions	Score
Movement of sediment in the channel is in equilibrium in terms of supply, erosion, and deposition processes that reflect the culturally unaltered condition. On higher-order streams there are alternating point bars; bank erosion occurs, but is stabilized and moderated by vegetation; and channel width, form, and floodplain area is consistent through the reach. In low-order streams with bedrock control, some of these indicators may not be apparent, but overall bank and hillslope erosion is moderated by vegetation, and there are no apparent culturally induced catastrophic failures.	5
Movement of sediment in the channel is in equilibrium with the current hydrologic regime, as opposed to a culturally unaltered condition, and exhibits an overall balance in terms of erosion and deposition processes. On higher-order streams there are alternating point bars; bank erosion occurs, but is stabilized and moderated by vegetation; and channel width, form, and floodplain area are consistent through the reach. In low-order streams with bedrock control, some of these indicators may not be apparent, but overall bank and hillslope erosion is moderated by vegetation, and no culturally induced catastrophic failures are apparent.	4
Sediment disequilibrium is minor and localized within the reach. This includes small, localized areas of bank protection, slumping, or encroachment on the floodplain and channel. This condition class also includes previously disrupted reaches on a recovery trajectory, such as deeply entrenched streams where downcutting has been arrested by structural grade control, and there is sufficient room for lateral channel migration and establishment of a functional floodplain within the incised channel.	3
Sediment erosion and deposition out of equilibrium. Water inflow is sediment rich or poor, or accelerated bank erosion exists. Channel not actively incising, but extensive disequilibrium is evident. Typical indicators include extensive bank slumping (erosion events that exceed any moderating influence of native vegetation), active gullies feeding into the reach from adjacent hillslopes, shoaling of sediments rather than deposition in sorted lateral and mid-channel bars. Apparently stable channels should be placed in this category if there is evidence of regular mechanical disruption, such as bulldozing of the channel bottom and clearing of riparian vegetation to improve flood conveyance.	2
Sediment dynamics within most of the reach are seriously disrupted. This includes reaches where no significant storage or recruitment of sediment occurs (i.e., reaches in underground tunnels/culverts, and reaches hardened with rock or concrete). It also includes reaches that are either actively incising or functioning as sediment traps (e.g., sediment basins). This also includes reaches that have been subject to recent changes likely to induce severe disequilibrium, such as extensive floodplain filling, change in slope, channel straightening, or other changes that are likely to cause channel downcutting during future high-flow events.	1

for feeding, resting, or breeding are directly affected by the displacement of native vegetation. Exotic plant species commonly encountered in the Otay watershed included: *Ambrosia psilostachya, Arundo donax, Brassica nigra, Cirsium vulgare, Cynodon dactylon, Eucalyptus* *globulus, Foeniculum vulgare, Medicago sativa, Nicotiana glauca, Ricinus communis, Rumex crispus, Schinus molle, Sonchus asper, Tamarix ramosissima,* and *Xanthium strumarium.*

This indicator was assigned an index by matching field observations to the description of condition in Table 9. The reference standard condition was defined as exotic plant species absent or rare composing ≤5% total vegetation biomass.

Table 9. Description of conditions for assigning Exotic Plant Species indicator score

Description of Condition	Index
Exotic plant species absent or rare composing ≤5% total vegetation biomass	5
Exotics present but localized and composing >5 and ≤20% of vegetation biomass	4
Exotics common and composing >20 and ≤50% of vegetation biomass	3
Exotics widespread and composing >50 and ≤75% of vegetation biomass	2
Exotics dominant and composing >75% of vegetation biomass	1

4.3.9 Riparian Vegetation Condition ($RVCF_{RR}$ / $RVCT_{RR}$)

Riparian vegetation condition indicates the condition of native riparian vegetation communities within the floodprone area of the main stem channel through a riparian reach. Much has been written about the importance of native riparian vegetation communities in the support of specific faunal groups such as amphibians (Brode and Bury 1984), birds (Hendricks and Rieger 1989), and fauna in general (Hubbard 1977; Faber et al. 1989; Knopf et al. 1988). In addition, the condition of vegetation on the floodprone areas and terraces of the riparian ecosystem can affect the rate at which water, sediment, and nutrients move from uplands through the riparian ecosystem to the stream channel (Peterjohn and Correll 1984, 1986; Osborne and Kovacic 1993; Barling and Moore 1994).

Under culturally unaltered conditions, a complex interaction of many factors such as the size of the watershed, discharge, channel geometry, substrate type, and slope determine the size of the area that typically supports riparian vegetation. In general, as stream orders increase, the width of the bankfull channel increases, and the size of the floodprone area supporting riparian vegetation increases. Thus, the floodprone area represents a scaled metric that can be applied consistently in different stream orders throughout a watershed. Floodprone area was determined in the field by projecting the elevation corresponding to two times the maximum depth of the bankfull channel until it intersected the surface of the adjacent floodplain / terrace on both sides of the main stem channel (Rosgen 1996; 5-20). Historical terraces are easily discerned in the field as distinct horizontal surfaces at increasing elevation above the current floodprone area.

This indicator was assigned a score by observing the condition of vegetation in the floodprone area and terraces in the riparian reach and matching these field observations to the descriptions in Table 10. In inaccessible reaches, field observations were supplemented with aerial photography and riparian vegetation community maps developed by Lichvar and Ericsson (2003). The reference standard condition was defined as presence of vegetation representing culturally unaltered reference conditions with no chronic cultural disturbances, or recovered from historical cultural disturbances.

Table 10. Description of conditions for assigning the Riparian Vegetation Condition indicator score

Description of Conditions	Score
Vegetation represents reference condition with no chronic cultural disturbance or recovered from historical disturbance. Presence of areas disturbed through natural processes (i.e., fire and flood) okay.	5
Native vegetation recovering with minor chronic disturbance (i.e., grazing). Presence of areas disturbed through natural processes (i.e., fire and flood) okay.	4
Native vegetation common and widespread with moderate grazing pressure. Presence of areas disturbed through natural processes (i.e., fire and flood) okay.	3
Native vegetation localized with heavy grazing pressure. Presence of areas disturbed through natural processes (i.e., fire and flood) okay.	2
Native vegetation absent, area hardened (i.e., paved, urban, etc.) or graded. Restoration impractical and unlikely for economic or political reasons.	1

4.3.10 Riparian Corridor Continuity (RCC_{RR} / RCC_{DB})

Riparian Corridor Continuity (RCC) indicates the degree to which the main stem channel of a riparian reach exhibits an uninterrupted vegetated riparian corridor. Riparian ecosystems typically form a relatively continuous corridor along the stream channel and floodplain. Intact vegetated corridors allow animals to move to locations throughout a watershed on a daily, seasonal, or annual basis (La Polla and Barrett 1993; Machtans et al. 1993; Naiman et al. 1993 and 1996), but see Simberloff et al. (1992). Gaps in the continuous riparian corridor can occur as a result of natural fluvial processes during large magnitude events (Hawkins et al. 1997). However, gaps are more frequently created as a result of cultural alterations such as roads, power and pipeline corridors, agriculture activities, and urban/industrial development.

This indicator was measured at the riparian reach scale as the percent of floodprone area along the main stem channel of the riparian reach occupied by native and non-native vegetation communities with adequate height and structure to allow faunal movement. For example, annual grassland with no shrub or tree component was considered to represent a corridor gap. The difference between this indicator and Area of Native Riparian Vegetation was that for the RCC indicator, the vegetation corridor could be composed of native or non-native riparian species, whereas for the NRV indicator, only native riparian vegetation communities were considered. The percent of floodprone area occupied by native riparian vegetation was estimated based on field observations, aerial photographs, and riparian vegetation communities mapped by Lichvar and Ericsson (2003). At the drainage basing scale, RCCwas calculated as the weighted average of the percent of RCC for all riparian reaches in the drainage basin of the riparian reach using the following formula:

$$\sum_{i=1}^{i_n}\left[RCC_{RR} * \left({ML_{RR}}/{ML_{DB}} \right)\right] \qquad (5)$$

Where: RRC_{RR} = % of main stem in a riparian reach with vegetation corridor gaps
ML_{RR} = Length of main stem channel in a riparian reach
ML_{DB} = Length of main stem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the floodplain of the main stem channel of the riparian reach occupied with riparian vegetation communities. Indicator scores were assigned based on the range of indicator values in Table 11.

Table 11. Range of indicator values for scaling the riparian corridor continuity indicators

Indicator Value Range	Score
≤5% of riparian reach with gaps/breaks due to cultural alteration	5
>5 and ≤15% of riparian reach with gaps/breaks due to cultural alteration	4
>15 and ≤30% of riparian reach with gaps/breaks due to cultural alteration	3
>30 and ≤50% of riparian reach with gaps/breaks due to cultural alteration	2
>50% of riparian reach with gaps/breaks due to cultural alteration	1

4.3.11 Riparian Ecosystem Buffer (BUF_{RR})

Land use/land cover immediately adjacent to the riparian ecosystem plays an important role in determining the ability of animals to move freely between riparian and adjacent upland ecosystems on a daily or seasonal basis (Petersen et al. 1992; Vought et al. 1994, Statzner et al. 1997; Vought et al. 1994; Osborne and Kovacic 1993). Under natural conditions, vegetation in the riparian ecosystem may gradually transitions to upland vegetation, particularly in higher order streams with larger floodplains. In other cases, the interface between the riparian ecosystem and uplands is quite abrupt. This is particularly true in lower order streams. A variety of cultural activities replace these native or naturalized vegetation communities with agriculture, grazing, urban/industrial, transportation corridors or other types of LULC that reduce the likelihood that wildlife can utilize the riparian ecosystem buffer, or move freely between the riparian ecosystem and adjacent upland habitats. Land Use/Land Cover in Riparian Ecosystem Buffer indicates the degree to which the LULC in a 300-foot buffer zone adjacent to the riparian ecosystem is unsuitable for wildlife usage and movement.

This indicator was measured using field observation and aerial photographs. A buffer of 300 feet in width was established around the perimeter of each riparian reach, and the percent of the buffer area considered to unsuitable for wildlife was determined. The reference condition was defined as <5% of the buffer zone be unsuitable for wildlife. Indicator scores were assigned based on the range of indicator values in Table 12.

Table 12. Range of indicator values for scaling the Riparian Ecosystem Buffer indicator

Metric Value Category	Score
≤5% of the buffer zone unsuitable for wildlife	5
>5 and ≤15% of the buffer zone unsuitable for wildlife	4
>15 and ≤30% of the buffer zone unsuitable for wildlife	3
>30 and ≤50% of the buffer zone unsuitable for wildlife	2
>50% of the buffer zone unsuitable for wildlife	1

4.3.12 Land Use/Land Cover ($LULCN_{LD}$ / $LULCP_{LD}$ / $LULCH_{LD}$ / $LULCS_{LD}$ / $LULCN_{DB}$ / $LULCP_{DB}$ / $LULCH_{DB}$ / $LULCS_{DB}$)

Land use/land cover (LULC) indicates the way in which a tract of land is utilized, has been developed, or the physiognomic class of vegetation. For example, a tract of land that is used to produce row crops is assigned an agricultural LULC, golf courses and parks are assigned to a recreational LULC, urban areas are typically assigned to a residential, industrial, or commercial LULC. Lands supporting natural vegetation communities (i.e., chaparral versus pasture) are assigned to a shrub, forest, grassland, or other native vegetation LULC. A variety of LULC classifications have been developed over the years. Today however, the reference to LULC usually implies the USGS classification of LULC (Anderson et al. 1976) or a similar, but more detailed regional variations of this classification. This type of LULC classification is typically developed through the interpretation of aerial photographs or the analysis of other remote sources of thematic information (USGS 1990).

Over the centuries, humans have modified the LULC of the natural landscape through intensive land management practices such as agriculture, forestry, and grazing, as well as through industrialization and urbanization. The net effect of these activities has been a dramatic shift in the type and extent of LULC that occur around the world today, particularly in industrialized countries (Meyer and Turner 1992; Hannah et al. 1994).

A number of studies have related LULC to water quality. While they have consistently shown that the water quality decreases as natural LULC are culturally altered, the specific relationships and causative factors vary widely. For example, Hunsaker and Levine found that LULC changes in the watershed had the greatest effect on water quality, while Graf 1998 found that changes in LULC in the surrounding landscape had the greatest effect. The relationship between LULC and quantity and quality of surface water has been documented for a variety of wetland and aquatic systems (Brugham 1978; Ehrenfield 1983; Kuenzler 1986; Howarth et al. 1991; Ryan 1991;Williamson et al. 1992; Richards and Host 1994; Cooper 1995; Blair 1996; Wilber et al. 1996; Caruso and Ward 1998). In the western United States specifically, livestock grazing, agriculture, and urbanization have often been identified as contributors to increased surface water runoff and non-point sources of sediment, nutrients, and other classes of pollutants (Armour et al. 1991; Sedgwick and Knopf 1991; Charbonneau and Kondolf 1993; Bush and Smith 1995; Rothrock et al. 1998).

Four indicators were used to measure the impact of existing LULC on water quality integrity. Each indicator was measured as the percent of the local drainage and drainage basin of a riparian reach with LULC types having the potential to increase the nutrient, pesticide, hydrocarbon, or sediment loading in downstream surface waters. Land use/land cover categories with the potential to increase these categories of pollutants are shown in Table 13. The basis for deciding whether or not a LULC category did, or did not, increase nutrients, pesticides, hydrocarbons, sediments, or was considered unsuitable as wildlife habitat was based on the review of available literature, and opinion of the author. It is easy to think of exceptions to the decision rules listed in Table 13. For example, agricultural lands can, and do, provide food resources for certain wildlife species. However, the decision rules are developed in the context of the reference condition for the suite of wildlife species that would have occupied the native vegetation communities replaced by the agricultural areas. Overall, it can be said that agricultural lands are generally unsuitable for the suite of wildlife species that would have occurred under reference conditions.

Using the ArcView GIS themes of riparian reach and LULC themes, the area of a local drainage occupied by each LULC was determined for each indicator. The area of LULC types with the potential to increase pollutants, hydrocarbons, nutrients, and sediment were then aggregated for the drainage basin and divided by the total drainage basin area to determine the indicator metric value.

Table 13. Land Use/Land Cover (LULC) types and their affects

Code	LULC Description	LULC Type Increases Nutrient Load	LULC Type Increases Pesticide Load	LULC Type Increases Hydro-carbon Load	LULC Type Increases Sediment Load	Unsuitable Wildlife Habitat
1	Agricultural	Yes	Yes	No	Yes	Yes
2	Commercial	No	No	Yes	No	Yes
3	Grazing	Yes	No	No	Yes	No
4	Industrial	Yes	Yes	Yes	No	Yes
5	Mining	No	No	Yes	Yes	Yes
6	Native Vegetation	No	No	No	No	No
7	Recreation	No	No	Yes	Yes	Yes
8	Residential	Yes	Yes	Yes	No	Yes
9	Rural Residential	Yes	Yes	Yes	Yes	Yes
10	Transportation / Utilities	No	Yes	Yes	No	Yes
11	Water	No	No	No	No	No

The reference condition was defined as <5% of the watershed and surrounding landscape area with LULC types with the potential to increase nutrient, pesticide, hydrocarbon, or sediment loading in surface waters downstream. Indicator scores were assigned based on the range of indicator values in Table 14.

Table 14. Range of indicator values for scaling the land use/land cover indicator

Indicator Value Range	Score
≤5% of local drainage or drainage basin with LULC types that increase N/P/H/S	5
>5 and ≤15% of local drainage or drainage basin with LULC types that increase N/P/H/S	4
>15 and ≤30% of local drainage or drainage basin with LULC types that increase N/P/H/S	3
>30 and ≤50% of local drainage or drainage basin with LULC types that increase N/P/H/S	2
>50% of local drainage or drainage basin with LULC types that increase N/P/H/S	1

4.3.13 Wildlife Habitat (WH_{LD})

The upland areas in the local drainage of the riparian ecosystems, like the buffer area adjacent to the riparian ecosystem, are important because of their ability to support various other life requirements of riparian ecosystem dependent wildlife species. Under reference conditions, these upland areas consist of native vegetation communities to which wildlife is adapted. A variety of cultural activities replace these native vegetation communities with agriculture, urban/industrial, transportation corridors, and other types of land use. Wildlife Habitat in the Local Drainage indicates the degree to which the LULC in the local drainage of the riparian ecosystem is suitable for wildlife usage.

This indicator was measured using the ArcView GIS themes of riparian reach and LULC. The percent of each LULC type in the local drainage of the riparian reach was determined. Land Use/Land Cover types unsuitable for wildlife were summed to determine the percent of the local drainage with LULC types unsuitable for wildlife. Table 13 indicates which LULC types were considered to be unsuitable.

The reference standard condition was defined as <5% of the LULC in local drainage unsuitable for wildlife. Indicator scores were based on the range of indicator values in Table 15.

Table 15. Range of indicator values for scaling the Wildlife Habitat indicator

Indicator Value Range	Score
≤5% of the LULC in local drainage unsuitable for wildlife	5
>5 and ≤15% of the LULC in local drainage unsuitable for wildlife	4
>15 and ≤30% of the LULC in local drainage unsuitable for wildlife	3
>30 and ≤50% of the LULC in local drainage unsuitable for wildlife	2
>50% of the LULC in local drainage unsuitable for wildlife	1

4.4 Integrity Indices

Integrity indices were developed for each of the hydrologic, water quality, and habitat integrity assessment endpoints. Each of these integrity indices is defined and discussed in terms of the assessment indicators in the following sections. Table 16 summarizes the information on which indicators are used in each integrity index.

4.4.1 Hydrologic Integrity Index

Riparian ecosystems with high hydrologic integrity exhibit the range of frequency, magnitude, and temporal distribution of stream discharge, and surface and subsurface interaction between the stream channel, floodplain, and terraces, that historically characterized riparian ecosystems in the region (Bedford 1996, Poff et al. 1997, Richter et al. 1997). In the arid southwest, this translates into seasonal intermittent, ephemeral, or low flow periods, with annual bankfull discharges superimposed on a background of episodic, and often catastrophic, larger magnitude floods that inundate historical terraces (Graf 1979; Graf 1988; Harris 1987; Fisher et al. 1982; Friedman et al. 1996a, Friedman et al. 1996b).

In selecting indicators to assess hydrologic integrity, two groups of characteristics and processes were considered. The first group focused on the factors that influence frequency, magnitude, and temporal distribution of stream discharge, and the second group focused on the factors that influenced the hydrologic interaction between the stream channel, floodplain, and historical terraces. Direct measures of stream discharge are unavailable at the riparian reach scale in these watersheds. Consequently, several indicators were selected at the drainage basin scale with the assumption that an indirect estimate of deviation from reference condition can be made based on changes in specific characteristic and processes of a drainage basin such as interception, infiltration, evapotranspiration, percolation, groundwater flow, and surface water flow overland and in channels. Cultural alteration of the drainage basin alters these characteristics and processes, and consequently, stream discharge. While it is difficult to quantify the exact nature of the relationship between specific drainage basin characteristics, as represented by the indicators, and stream discharge, it can generally be shown that as cultural alteration of a watershed increases, so does the deviation from short and long-term historical patterns of frequency, magnitude, and distribution of stream discharge.

Table 16. Indictors used for calculation of integrity indices

#	Indicators	Hydrologic Integrity Index Indicators	Water Quality Integrity Index Indicators	Habitat Integrity Index Indicators
1	Improved Hydraulic Conveyance - Riparian Reach (IHC_{RR})	X[1]	X[1]	
2	Improved Hydraulic Conveyance - Blue Line Tributaries (IHC_{RRT})	X[1]	X[1]	
3	Improved Hydraulic Conveyance - Drainage Basin (IHC_{DB})	X[1]	X[1]	
4	Perennialized Stream Flow - Riparian Reach (PSF_{RR})	X	X	
5	Perennialized Stream Flow (PSF_{DB})	X[1]	X[1]	
6	Floodplain Interaction (*FI*)	X	X	
7	Surface Water Retention - Riparian Reach (SWR_{RR})	X	X	
8	Surface Water Retention (SWR_{DB})	X[1]	X[1]	
9	Import, Export, or Diversion - Riparian Reach (IED_{RR})	X	X	
10	Import, Export, or Diversion - Drainage Basin (IED_{DB})	X[1]	X[1]	
11	Imperviousness - Local Drainage (IMP_{LD})	X	X	
12	Sediment Regime Index - Riparian Reach (SR_{RR})		X	
13	Exotic Plant Species - Riparian Reach (EXO_{RR})			X
14	Riparian Vegetation Condition - Floodprone Area ($RVCF_{RR}$)		X	X
15	Riparian Vegetation Condition - Terraces ($RVCT_{RR}$)			X
16	Riparian Corridor Continuity - Riparian Reach (RCC_{RR})			X
17	Riparian Corridor Continuity - Drainage Basin (RCC_{DB})			X
18	Riparian Buffer ($BUFF_{RR}$)			X
19	Land Use Land Cover - Nutrients - Drainage Basin ($LULCN_{DB}$)		X	

[1] Indicators averaged in the index

Table 16. cont.

#	Indicators	Hydrologic Integrity Index Indicators	Water Quality Integrity Index Indicators	Habitat Integrity Index Indicators
20	Land Use Land Cover - Pesticides - Drainage Basin ($LULCP_{DB}$)		X	
21	Land Use Land Cover - Hydrocarbons - Drainage Basin ($LULCH_{DB}$)		X	
22	Land Use Land Cover - Sediment - Drainage Basin ($LULCS_{DB}$)		X	
23	Land Use Land Cover - Nutrients - Local Drainage ($LULCN_{LD}$)		X	
24	Land Use Land Cover - Pesticides - Local Drainage ($LULCP_{LD}$)		X	
25	Land Use Land Cover -Hydrocarbons - Local Drainage ($LULCH_{LD}$)		X	
26	Land Use Land Cover - Sediment - Local Drainage ($LULCS_{LD}$)		X	
27	Wildlife Habitat - Local Drainage (WH_{LD})			X
Possible Minimum/Maximum Indicator Score Sum		7 / 35	10 / 50	7 / 35

Indicators selected to reflect degree of cultural alteration in a drainage basin with the potential to influence stream discharge included:

Improved Hydraulic Conveyance - Drainage Basin
Perennialized Stream Flow - Drainage Basin
Surface Water Retention - Drainage Basin
Import, Export, or Diversion of Surface Water - Drainage Basin

A frequency, magnitude, and distribution of stream discharge that is similar to the historical range of conditions does not alone, ensure hydrologic integrity. Hydrologic integrity also depends on maintaining the interaction between the stream channel, floodplain, and terraces of the riparian ecosystems through overbank and subsurface flows. This interaction is critical to the maintenance of riparian plant communities, sediment storage, carbon dynamics, biogeochemical processes, and other characteristics and processes of riparian ecosystems.

Indicators selected to represent the degree of interaction between the stream channel and the floodplain at the riparian reach and riparian reach tributary spatial scale included:

Improved Hydraulic Conveyance - Riparian Reach
Improved Hydraulic Conveyance - Blue Line Tributaries
Perennialized Stream Flow - Riparian Reach
Surface Water Retention - Riparian Reach
Import, Export, or Diversion of Surface Water - Riparian Reach
Riparian Vegetation Condition - Floodprone Area
Floodplain Interaction - Riparian Reach

These indicators were used to calculate the Hydrologic Integrity Index for each riparian reach using the procedure described Section 4.5.

4.4.2 Water Quality Integrity Index

Water quality integrity was defined as exhibiting a range of loading in the pollutant categories of nutrients, pesticides, hydrocarbons, and sediments that are similar to those that historically characterized riparian ecosystems in the region. Assessing changes in the range of loading in each pollutant category can be determined directly by comparing data on current loading with data on historical loading when such data are available. While there is some historical and recent monitoring data available for a limited number of stations in the watershed, little or no loading data are available at the riparian reach scale. Consequently, the assessment of water quality integrity was based on indicators of drainage basin and riparian reach characteristics that have been shown to influence water quality integrity.

Three groups of factors were considered in selecting indicators for the water quality integrity endpoint. The first group focused on whether the changes in land use in the drainage basin had the potential to increase sources of pollution compared to the reference condition. The second group focused on whether the stream channel delivery system had changed in relation to reference condition in terms of frequency, magnitude, and temporal distribution of stream flow (Kuenzler 1977). The third group focused on whether changes in land use in the areas adjacent to the stream, or the loss of a hydrologic connection between the stream channel and the floodplain had decreased the likelihood of pollutants being physically captured or biogeochemically processed compared to reference condition. A number of studies have shown that cultural alteration of these factors can lead to increased loading in one or more pollutant categories (Osborne and Wiley 1988; Allan and Flecker 1993; Hunsaker and Levine 1995; Perry and Vanderklein 1996; Richards et al. 1996; Allen et al. 1997; Bolstad and Swank 1997; Johnson et al. 1997; Wang et al. 1997; Miltner and Rankin 1998; Trimble 1997; Basnyat et al. 1999).

The following indicators were selected to reflect how the condition of land use in the drainage basin influences water quality integrity:

Land Use / Land Cover – Nutrient Increase - Local Drainage
Land Use / Land Cover – Nutrient Increase - Drainage Basin
Land Use / Land Cover – Pesticide Increase - Local Drainage
Land Use / Land Cover – Pesticide Increase - Drainage Basin
Land Use / Land Cover – Hydrocarbon Increase - Local Drainage
Land Use / Land Cover – Hydrocarbon Increase - Drainage Basin
Land Use / Land Cover – Sediment Increase - Local Drainage
Land Use / Land Cover – Sediment Increase - Drainage Basin

Nine indicators were selected to reflect the condition of the stream system that transports pollutants. These are the same indicators used in assessing hydrologic integrity, and included:

Improved Hydraulic Conveyance - Riparian Reach
Improved Hydraulic Conveyance - Blue Line Tributaries
Improved Hydraulic Conveyance - Drainage Basin
Perennialized Stream Flow - Riparian Reach
Perennialized Stream Flow - Drainage Basin
Surface Water Retention - Riparian Reach

Surface Water Retention - Drainage Basin
Import, Export, or Diversion of Surface Water - Riparian Reach
Import, Export, or Diversion of Surface Water - Drainage Basin

Indicators selected to reflect the condition of riparian ecosystem in terms of its ability to physically capture and biogeochemically process pollutants and thereby influence water quality included:

Floodplain Interaction - Riparian Reach
Sediment Regime - Riparian Reach
Riparian Vegetation Condition Floodprone Area - Riparian Reach

These indicators were used to calculate the Water Quality Integrity Index for each riparian reach using the procedure described in Section 4.5.

4.4.3 Habitat Integrity Index

Riparian ecosystems with habitat integrity exhibit the quality and quantity of habitat necessary to support and maintain a balanced, integrated, adaptive biological system having the full range of characteristics, processes, and organisms at the site specific, landscape, and watershed scales that historically characterized riparian ecosystems in the region. The following factors were considered in selecting indicators of habitat integrity including the spatial extent and quality of riparian habitat, the "connectedness" of riparian habitats at the riparian reach and drainage basin scales, and the spatial extent and quality of upland habitat in the landscape adjacent to riparian ecosystems:

Riparian Vegetation Condition - Floodprone Area - Riparian Reach
Riparian Vegetation Condition - Terraces - Riparian Reach
Exotic Species Index - Riparian Reach
Riparian Corridor Continuity - Riparian Reach
Riparian Corridor Continuity - Drainage Basin
Culturally Altered Land Use/Land Cover in 300' Buffer - Riparian Reach
Wildlife Habitat - Local Drainage - Riparian Reach

These indicators were used to calculate the Habitat Integrity Index for each riparian reach using the procedure described in Section 4.5.

4.5 Assigning Indicator Scores and Calculation of Integrity Indices

To calculate integrity indices, indicator values (i.e., percent deviation from reference condition 0-100) were converted to scores. Indicator values were assigned a score of 1-5 based on the relationship between indicator values and scores defined in Tables 2-15. Using the improved hydrologic conveyance indicator as an illustration (see Table 2), if the value of the altered hydrologic conveyance indicator for a riparian reach was <5%, a score of 5 was assigned to that riparian reach. If the value of the altered hydrologic conveyance indicator for a riparian reach was >30% and <50%, a score of 2 was assigned to that riparian reach. A score of 5 represented close concurrence with the reference condition, and consequently a high level of integrity. A score of 1 represented a deviation of 50% or more the reference condition, and consequently a low level of integrity.

Initial category ranges for indicator values were based on the natural groupings of the data collected during the project, and the subjective integration of numerous field observations relating indicator values to endpoint integrity. Testing of other category ranges (i.e., correlation analysis using quartiles and quintiles) showed no significant change in the relationship between riparian reaches in terms of either indicator scores or endpoint indices. Thus, initial category ranges were retained.

Integrity indices were calculated using the following equations:

Hydrologic Integrity Index

$$\begin{aligned}&\left(\left(IHC_{RR} + IHC_{RRT}\right)/\,2\right) + PSF_{RR} + SWR_{RR} + IED_{RR} + \\ &\left(\left(IHC_{DB} + PSF_{DB} + SWR_{DB} + IED_{DB}\right)/\,4\right) + FI_{RR} + IMP_{RR}\end{aligned} \tag{6}$$

Where:

IHC_{RR} = Improved Hydraulic Conveyance of main stem in riparian reach
IHC_{RRT} = Improved Hydraulic Conveyance of on blueline tributaries
IHC_{DB} = Improved Hydraulic Conveyance in drainage basin
PSF_{RR} = Perennialized Stream Flow of main stem in riparian reach
PSF_{DB} = Perennialized Stream Flow in drainage basin
SWD_{RR} = Surface Water Detention of main stem in riparian reach
SWD_{DB} = Surface Water Detention in drainage basin
IED_{RR} = Import, Export, or Diversion of surface water of main stem in riparian reach
IED_{DB} = Import, Export, or Diversion of surface water in drainage basin
FI_{RR} = Floodplain Interaction of main stem in riparian reach
IMP_{LD} = Imperviousness of local drainage

Water Quality Integrity Index

$$\begin{aligned}&\left(\left(IHC_{RR} + IHC_{RRT}\right)/2\right) + PSF_{RR} + SWR_{RR} + IED_{RR} + SR_{RR} + RVCF_{RR}\\&\left(\left(IHC_{DB} + PSF_{DB} + SWR_{DB} + IED_{DB}\right)/4\right) +\\&FI_{RR} + IMP_{RR} + \left(\left(LULCN_{DB} + LULCP_{DB} + LULCH_{DB} + LULCS_{DB}\right)/4\right) +\\&\left(\left(LULCN_{LD} + LULCP_{LD} + LULCH_{LD} + LULCS_{LD}\right)/4\right)\end{aligned} \tag{7}$$

Where:

IHC_{RR} = Improved Hydraulic Conveyance of main stem in riparian reach
IHC_{RRT} = Improved Hydraulic Conveyance of on blueline tributaries
IHC_{DB} = Improved Hydraulic Conveyance in drainage basin
PSF_{RR} = Perennialized Stream Flow of main stem in riparian reach
PSF_{DB} = Perennialized Stream Flow in drainage basin
SWR_{RR} = Surface Water Retention of main stem in riparian reach
SWR_{DB} = Surface Water Retention in drainage basin
IED_{RR} = Import, Export, or Diversion of surface water of main stem in riparian reach
IED_{DB} = Import, Export, or Diversion of surface water in drainage basin
SR_{RR} = Sediment Regime Index
$RVCF_{RR}$ = Riparian Vegetation Condition – Floodprone Area
FI_{RR} = Floodplain Interaction of main stem in riparian reach
IMP_{LD} = Imperviousness of local drainage
$LULCN_{DB}$ = Land Use Land Cover in drainage basin increasing nutrients
$LULCP_{DB}$ = Land Use Land Cover in drainage basin increasing pesticides
$LULCH_{DB}$ = Land Use Land Cover in drainage basin increasing hydrocarbons
$LULCS_{DB}$ = Land Use Land Cover in drainage basin increasing sediments
$LULCN_{LD}$ = Land Use Land Cover in local drainage increasing nutrients
$LULCP_{LD}$ = Land Use Land Cover in local drainage increasing pesticides
$LULCH_{LD}$ = Land Use Land Cover in local drainage increasing hydrocarbons
$LULCS_{LD}$ = Land Use Land Cover in local drainage increasing sediments

Habitat Integrity Index

$$RCC_{RR} + RCC_{DB} + RVCF_{RR} + RVCT_{RR} + EXO_{RR} + WH_{LD} + BUF_{RR} \tag{8}$$

Where:

RCC_{RR} = Riparian Corridor Connectivity of main stem in riparian reach
RCC_{DB} = Riparian Corridor Connectivity in drainage basin
$RVCF_{RR}$ = Vegetation Condition on floodplain
$RVCT_{RR}$ = Vegetation Condition on terrace
EXO_{RR} = Exotic Species in riparian ecosystem
WH_{LD} = Wildlife Habitat in local drainage
BUF_{RR} = Alterations to 300' Buffer

4.6 Archiving of Information

All of the information and data collected during the delineation, characterization, and assessment of riparian reaches, as well as results derived from this information were archived in ArcView and Excel spreadsheets. Appendices 1 and 3 discuss the archiving of this information in each format.

5.0 Results and Discussion

Two hundred and twelve riparian reaches were identified in the Otay River watershed. The length of main stem channel in these reaches ranged from 320 to 32,400 feet, and the size of the local drainages of these riparian reaches ranged from 4 to 3,319 acres. The wide range in these two characteristics reflects the significant differences between urban areas and more natural landscapes in terms of the longitudinal homogeneity of vegetation cover, engineering, and other types of disturbance that occur along stream channels and their associated riparian ecosystems.

The minimum, maximum, and mean of indicator values, and the frequency of indicator scores for all riparian reaches are summarized in Table 17. The range of values for the index of hydrologic integrity was 14 to 35 (35 possible) with a mean of 30. The range of values for the index of water quality integrity was 21 to 55 (55 possible) with a mean of 40. The range of values for the habitat integrity index was 7 to 35 (35 possible) with a mean of 21. Figures 7, 8, and 9 show the distribution of integrity indices for all riparian reaches in terms of hydrologic, water quality, and habitat integrity respectively. In general, the index values exhibited a relatively wide and even spread across the possible range of index values. These results can be interpreted as evidence that the indicators were scaled appropriately, and sensitive enough to distinguish varying degrees of hydrologic, water quality, and habitat integrity. The results are consistent with the perception of riparian ecosystem integrity in the watershed based on extensive field-work and observations. Ultimately, however, the only way to increase confidence in the integrity indices is through testing and verification with more quantitative models of hydrologic, water quality, and habitat integrity.

Because of the extensive amount of data collected for each riparian reach and the inherently spatial nature of the data, the Excel spreadsheet and ArcView software are much better formats for reviewing results of the baseline assessment. Consequently, the objective here will be to provide examples and illustrations to acquaint readers with the way in which results can be presented and summarized in Excel and ArcView.

Table 17. Descriptive statistics for Otay River watershed indicator metric values and scores

#	Indicator	Minimum Metric Value / Score	Maximum Metric Value / Score	Mean Metric Value / Score	Frequency of Scores				
					Score 1	Score 2	Score 3	Score 4	Score 5
1	IHC_{RR}	0	100	11.8	19	5	15	8	165
2	IHC_{RRT}	0	100	9.6	16	5	9	7	175
3	IHC_{DB}	0	100	8.4	13	1	8	29	161
4	PSF_{RR}	0	100	12.7	25	2	0	0	185
5	PSF_{DB}	0	100	8.0	14	5	5	20	168
6	FI_{RR}	0	100	5.2	9	1	2	6	194
7	SWD_{RR}	0	100	13.6	25	6	7	4	170
8	SWD_{DB}	0	100	6.9	4	5	17	52	134
9	IED_{RR}	0	100	6.1	13	0	0	0	199
10	IED_{DB}	0	100	50.1	118	5	2	0	87
11	IMP_{RR}	1^*	5^*	3.2^*	4	31	101	59	17
12	SR_{RR}	1^*	5^*	3.1^*	14	55	69	45	29
13	EXO_{RR}	1^*	5^*	3.4^*	18	37	53	60	44
14	RVC_{F}	1^*	5^*	3.0^*	12	53	92	37	18
15	RVC_{T}	1^*	5^*	3.1^*	14	49	80	49	20
16	RCC_{RR}	0	100	37.9	64	25	44	25	54
17	RCC_{DB}	0	100	35.4	55	33	67	29	28
18	BUF_{RR}	0	100	52.3	55	33	67	29	28
19	$LULC_{LD}$ (Average)	0	100	40.7	144	31	19	7	11
20	$LULC_{DB}$ (Average)	0	100	37.4	134	26	24	12	17
21	WH_{LD}	0	100	27.5	52	18	17	15	110
* Indicator metric is recorded directly as a score 1-5									

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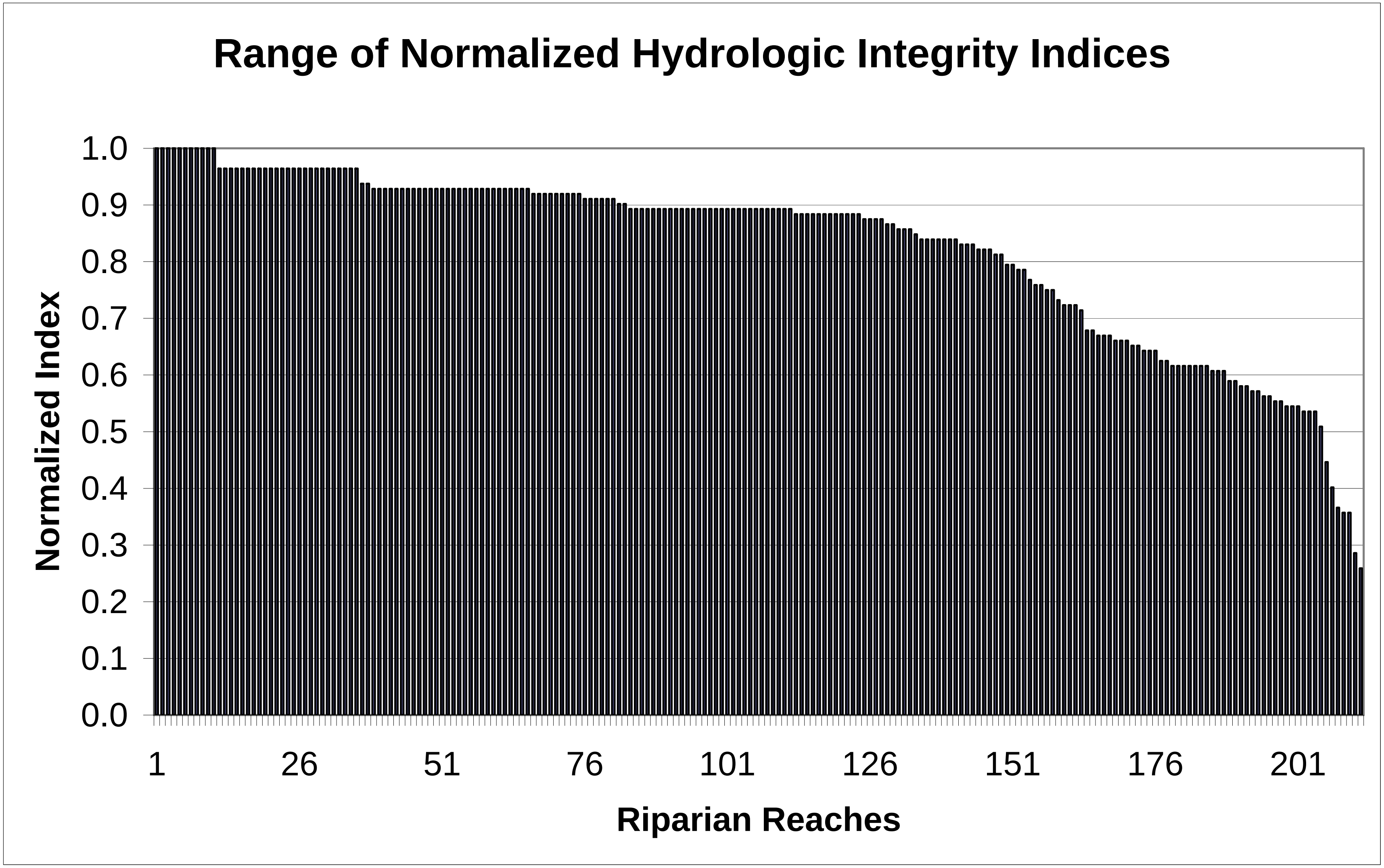


Figure 7. Summary of normalized indices of hydrologic integrity

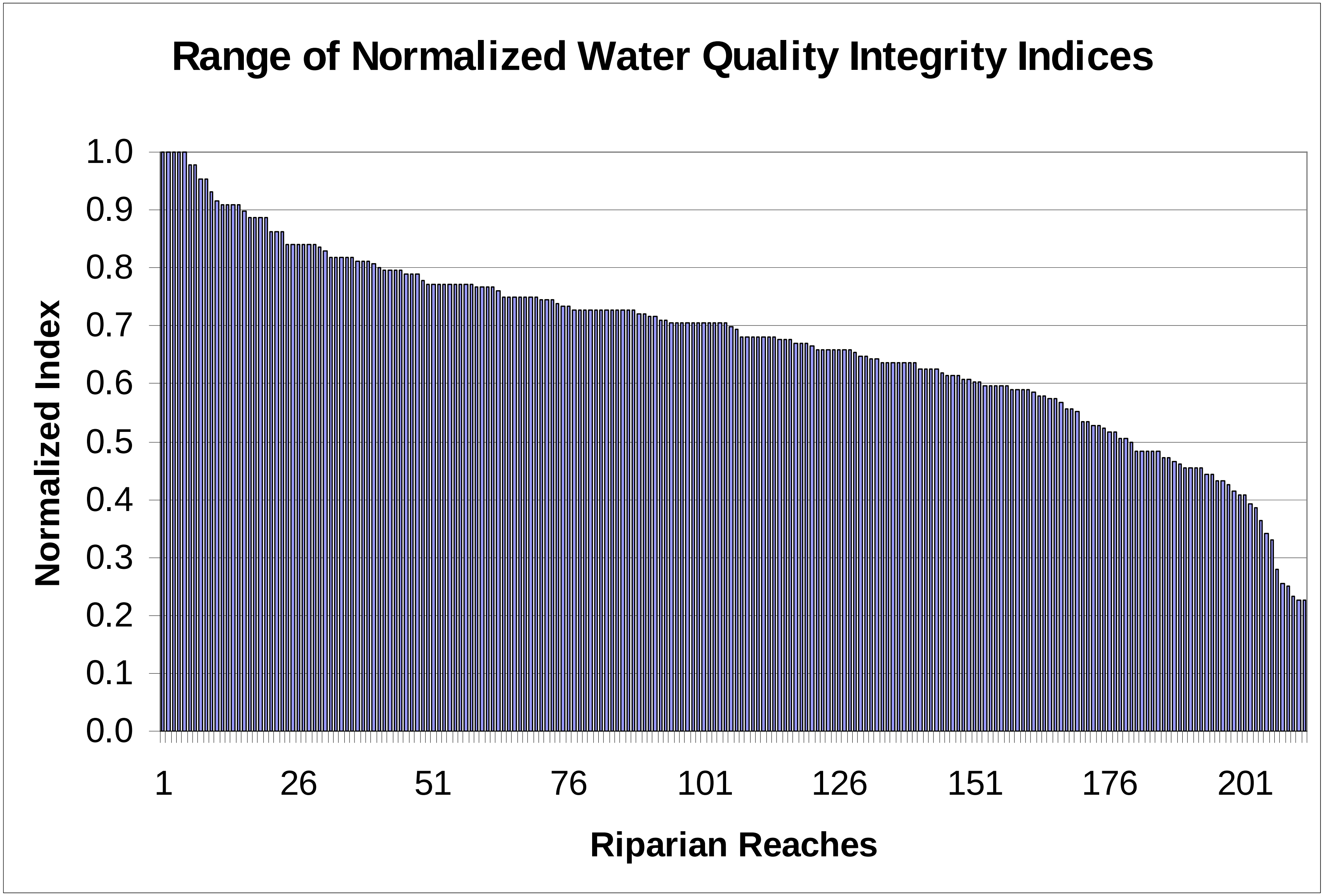


Figure 8. Summary of normalized indices of water quality integrity

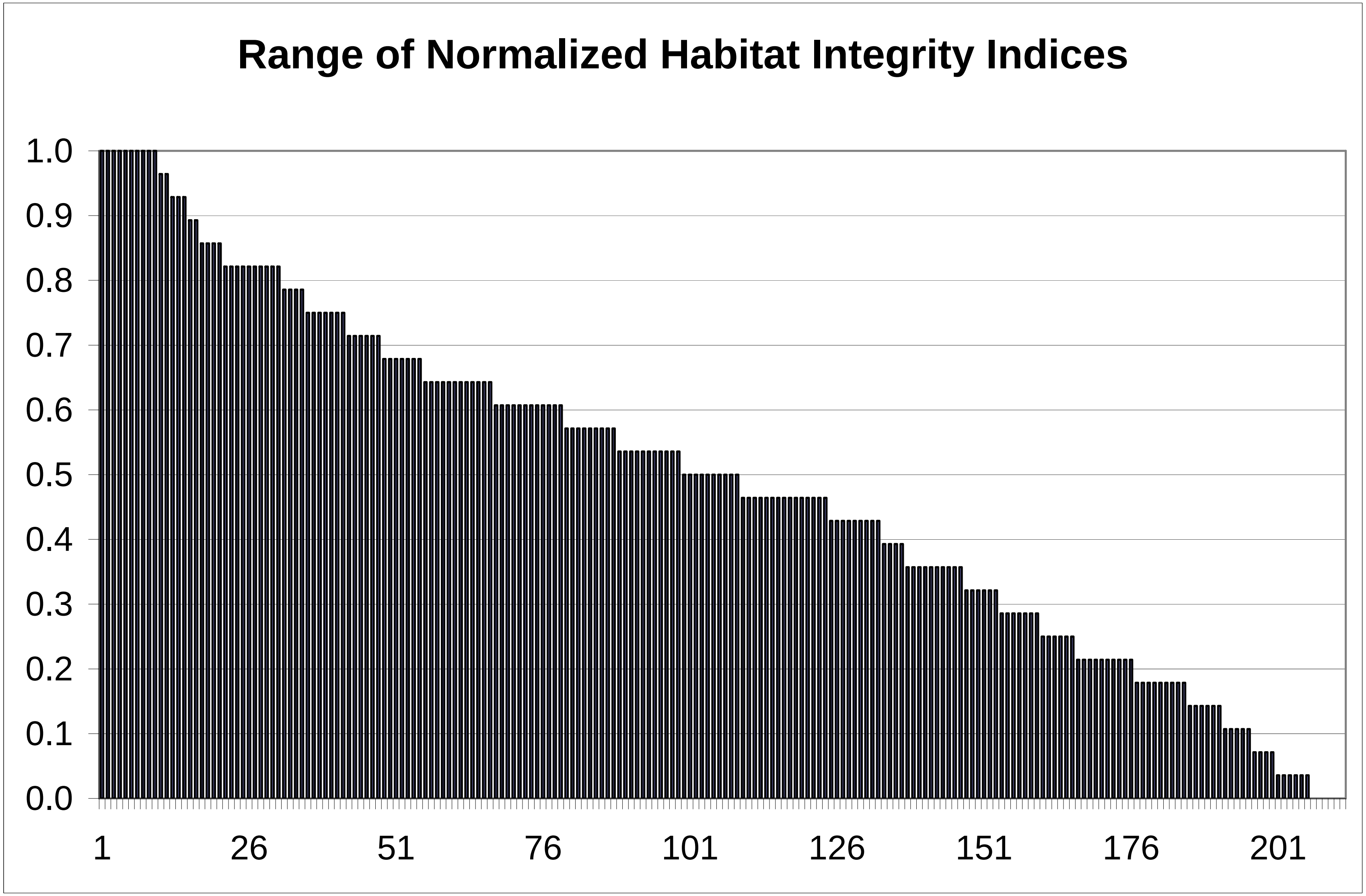


Figure 9. Summary of normalized indices of habitat integrity

Figure 10 is an ArcView layout showing the location of riparian reaches, main stems, and blue line tributaries in the Otay River watershed. The polygons represent the local drainage boundaries of riparian reaches.

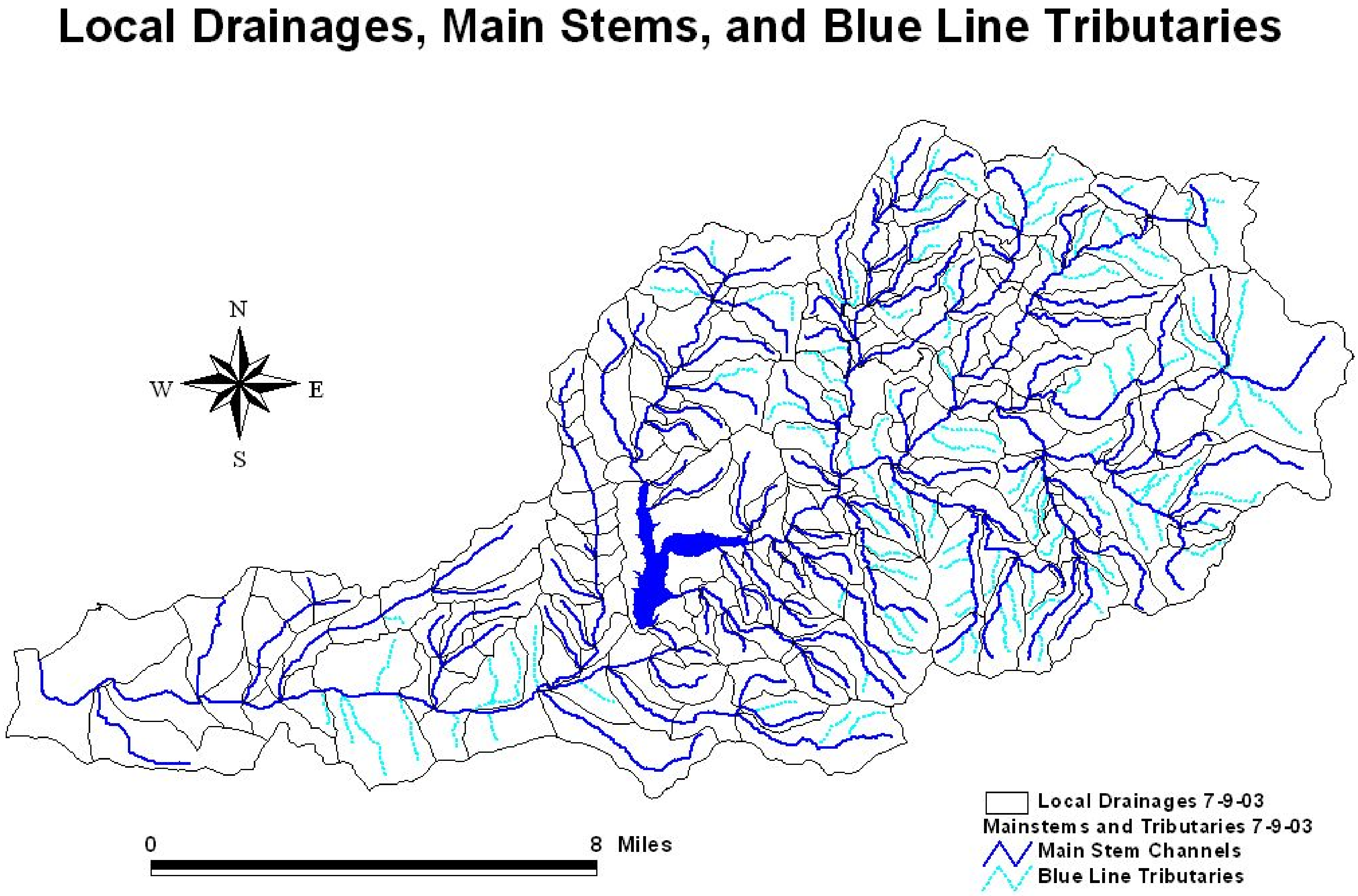
Figure 11 shows the Otay River watershed in the vicinity of Jamul Creek and Dulzura Creek confluence. Polygons again represent the local drainage boundaries of riparian reaches. The green stippled areas are riparian ecosystems. Blue lines are non-wetland waters stream channels mapped by Lichvar and Ericsson (2003).

Figure 12 compares indictor scores for some of the riparian reaches in Sycamore Canyon.

Figure 13 shows how a summary of the results of the baseline assessment can be displayed in ArcView. The color of each riparian reach polygon represents the normalized hydrologic integrity index of the riparian reach. The gradient of color from light to dark green makes it easy to visually identify areas of high hydrologic integrity in the watershed. Individuals with personal knowledge of the watershed will recognize that index values are lower in areas of urban and agricultural development and higher in the more remote, undeveloped areas. Figures 14 and 15 illustrate the results for water quality and habitat integrity indices.

6.0 Future Tasks

The results of the baseline assessment make it possible to analyze and compare how different alternative development scenarios impact riparian ecosystem integrity. The impacts of alternative development scenarios are determined by simulating the changes to indicators (i.e., changes in land use, hydraulic conveyance, etc.) that can be expected to occur as a result implementing the alternative development scenario and the calculating post-project integrity indices for each riparian reach. Then, the baseline assessment integrity indices for each riparian reach can be compared to the pre- and post-project integrity indices for each riparian reach resulting from each alternative development scenario to see how alternative development scenarios differentially impact riparian ecosystem integrity in the watershed



Local Drainages, Main Stems, and Blue Line Tributaries

Figure 10. Otay River watershed showing local drainage boundaries, main stems, and blue line tributaries

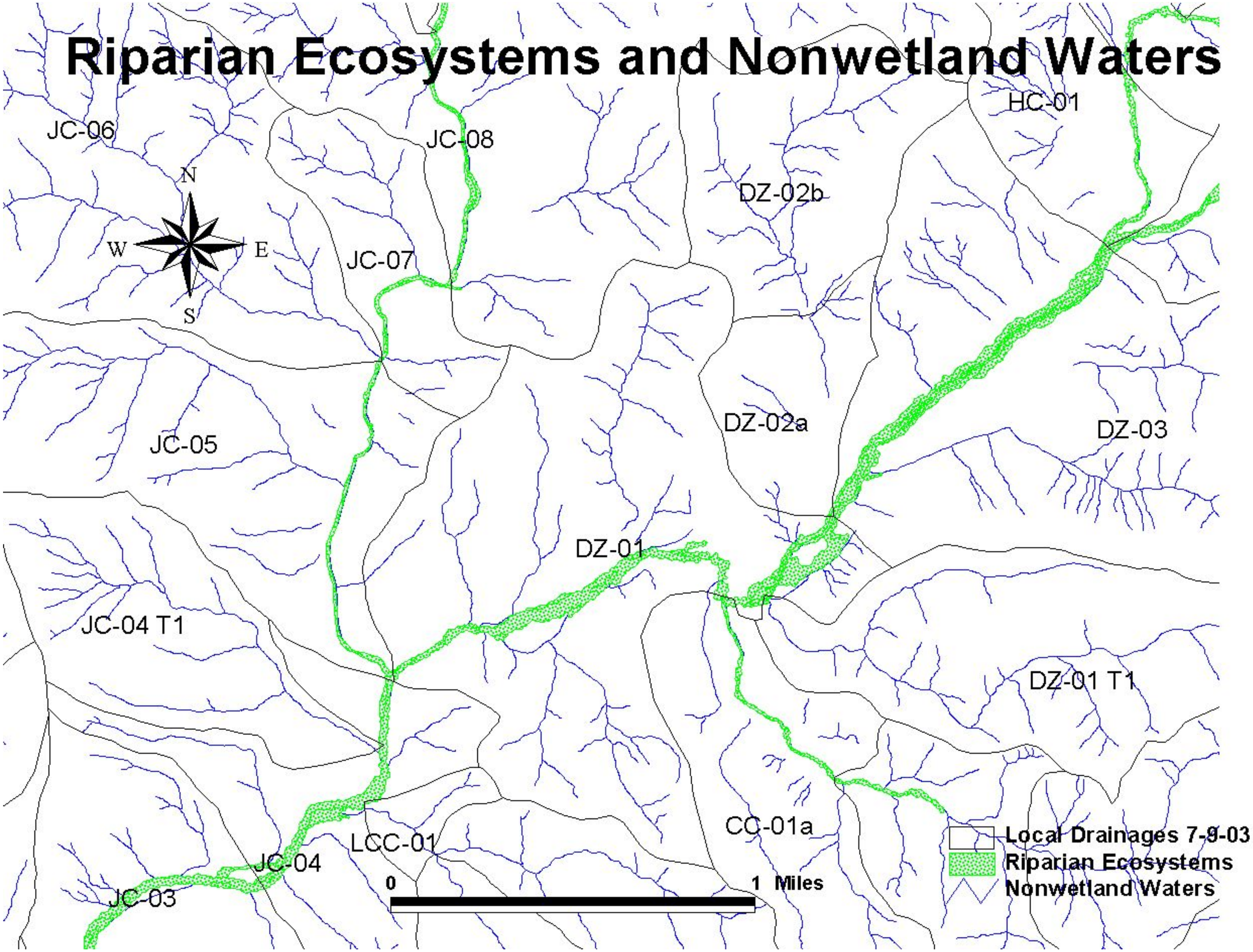


Figure 11. Riparian ecosystems and nonwetland waters

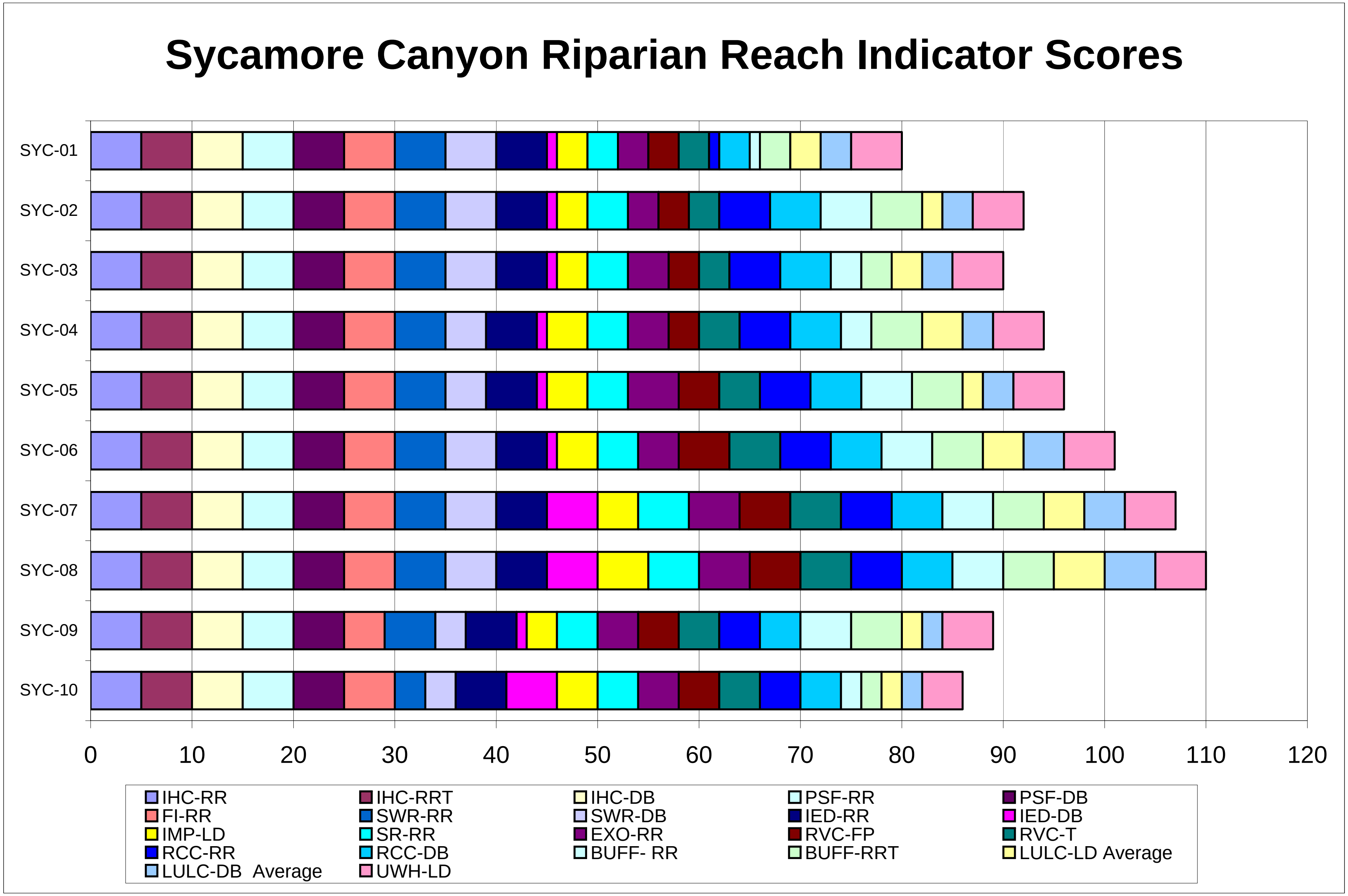


Figure 12. Indictor scores for Sycamore Canyon riparian reaches (indicator codes are shown in Table 16)

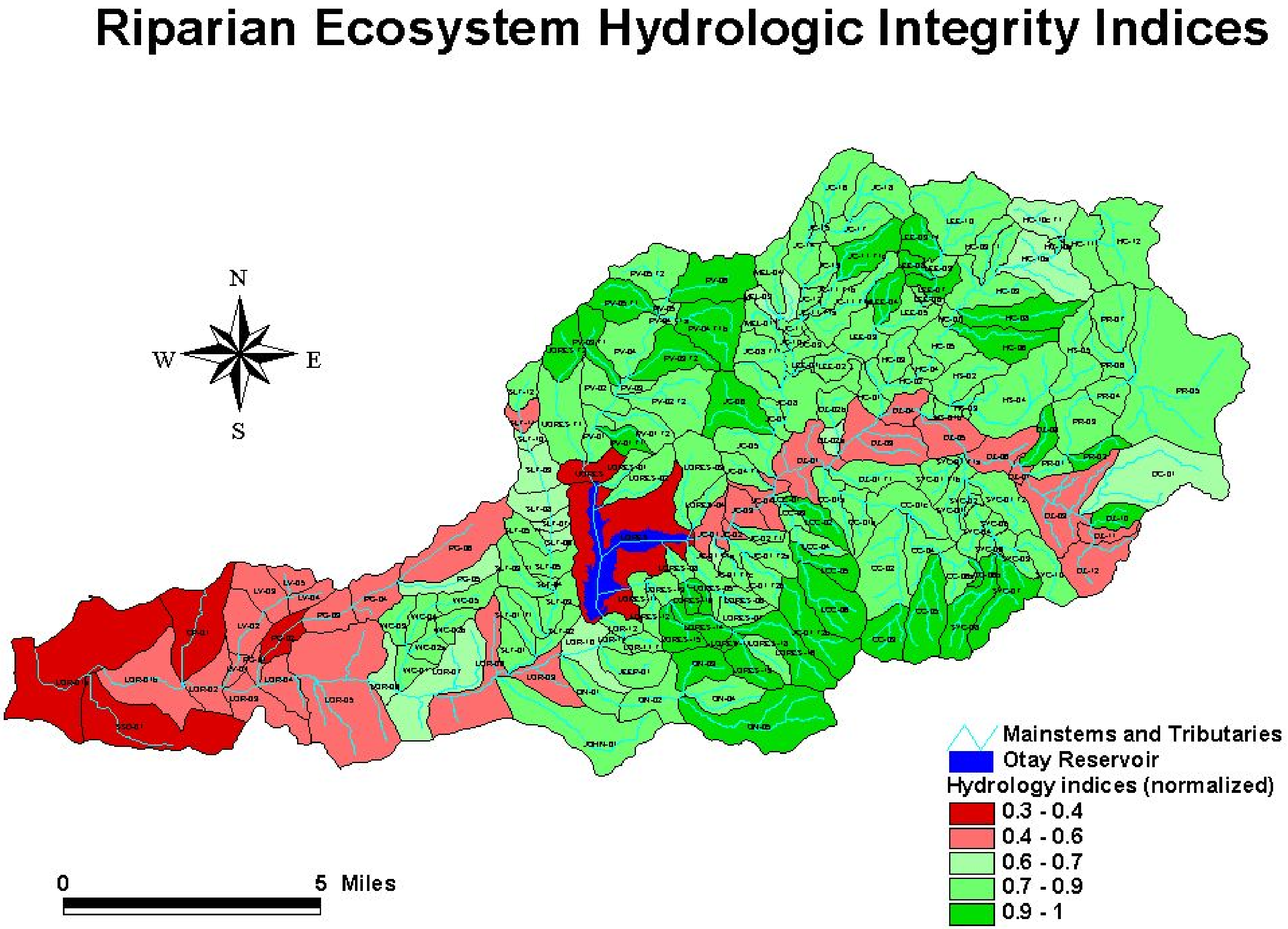


Figure 13. Hydrologic integrity indices for riparian reaches extrapolated to local drainages

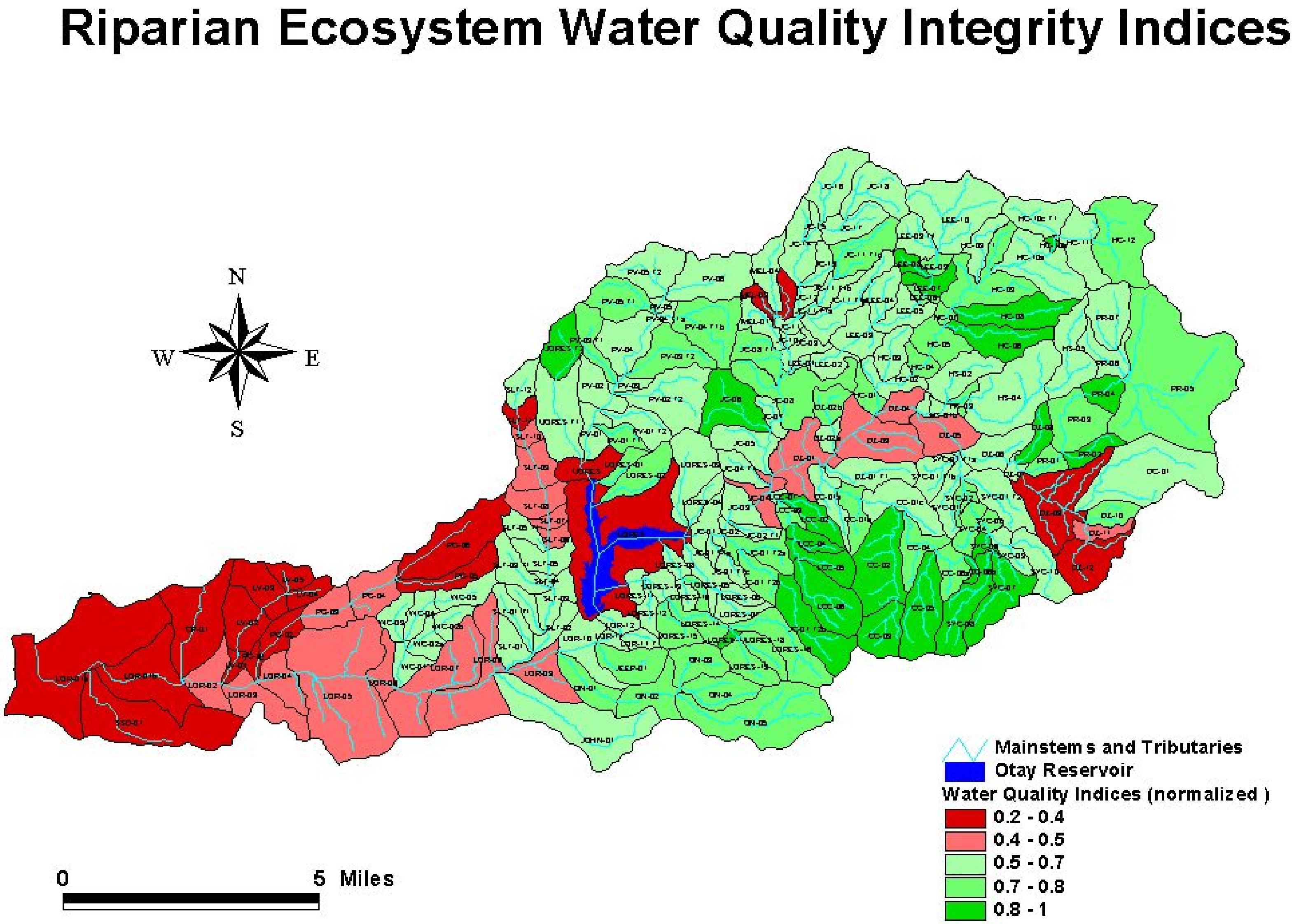


Figure 14. Water Quality integrity indices for riparian reaches extrapolated to local drainages

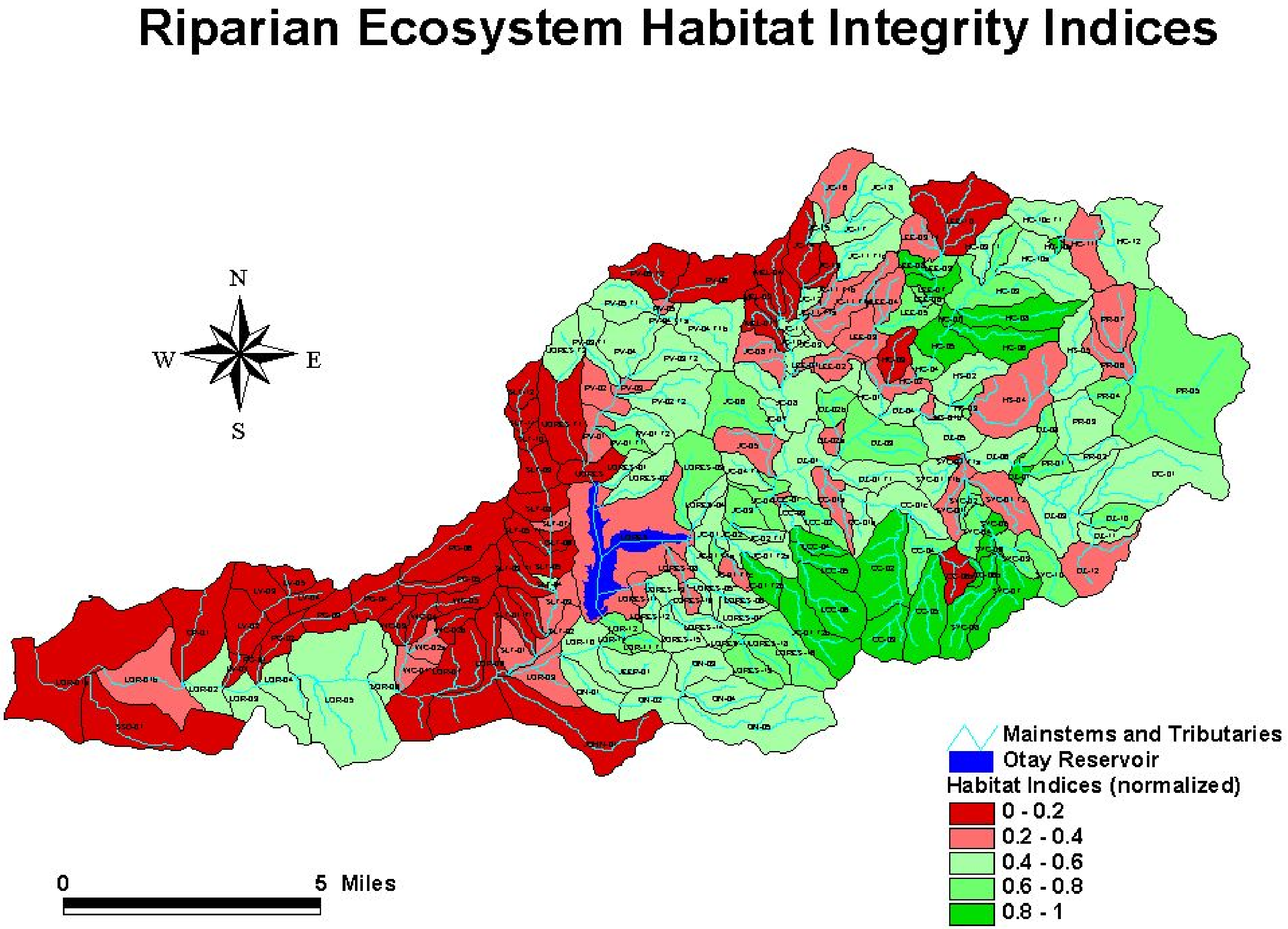


Figure 15. Habitat integrity indices for riparian reaches extrapolated to local drainages

7.0 Literature Cited

Abbruzzese, B. and S.G. Leibowitz. 1997. A Synoptic Approach for Assessing Cumulative Impacts to Wetlands. Environmental Management 21:457-475.

Allan, J.D. and A.S. Flecker. 1993. Biodiversity conservation in running waters. BioScience 43: 32-43.

Allan, J.D., D.L. Erickson, and J. Fay. 1997. The influence of catchment land use on stream integrity across multiple scales. Freshwater Biology 37:149-161.

Anderson, J.R., E. E. Hardy, J.T. Roach, R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper 964. U.S. Geological Survey, Reston, VA. 28 pages.

Armour, C.L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16: 7-11.

Bain, M.B., J.T. Finn, and H.E. Booke. 1988. Streamflow regulation and fish community structure. Ecology 69:382-92.

Barling, R.D. and I.D. Moore. 1994. Role of buffer strips in management of waterway pollution: a review. Environmental Management 18:543-558.

Barnes, H.H. 1967. Roughness characteristics of natural channels. U.S. Geological Survey Water Supply Paper 1849. Washington, D.C.

Basnyat, P., L.D. Teeter, K.M. Flynn, B.G. Lockaby. 1999. Relationship between landscape characteristics and nonpoint source pollution inputs to coastal estuaries. Environmental Management 23: 539-549.

Bedford, B.L. 1996. The need to define hydrologic equivalence at the landscape scale for freshwater wetland mitigation. Ecological Applications 61: 57-68.

Bell, G. 1997. Ecology and management of *Arundo donax*, and approaches to riparian habitat restoration in Southern California. Pages 103-113 *in* Plant Invasions: Studies from North America and Europe. Blackhuys Publishers, Leiden, The Netherlands.

Benke, A, E Willeke, F. Parrish and D. Stites. 1981. Effects of urbanization on stream ecosystems. Completion report Project No. A-055-GA. Office of Water Research and Technology. US Dept. of Interior.

Blair, R.B. 1996. Land use and avian species diversity along an urban gradient. Ecological Applications 6:506-519.

Bockstael, N.E. 1996. Modeling economics and ecology: the importance of a spatial perspective. American Journal of Agricultural Economics 78: 1168-1180.

Bohn, T. and P.A. Amundsen. 2001. The Competitive Edge of an Invading Specialist. Ecology 82: 2150-2162.

Bolstad, P.V. and W.T. Swank. 1997. Cumulative impacts of land use on water quality in a southern Appalachian watershed. Journal of the American Water Resources Association 33: 519-533.

Booth, D. 1991. Urbanization and the natural drainage system-impacts, solutions and prognoses. Northwest Environmental Journal. 7(1): 93-118

Bovee, K. and J.R. Zuboy. 1988. Proceedings of a Workshop on the Development and Evaluation of Habitat Suitability Criteria. U.S. Fish and Wildlife Service Biological Report 88 (11). Washington, D.C.

*Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. Wetlands Research Program Technical Report WRP-DE-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Brode, J.M. and R.B. Bury. 1984. The importance of riparian systems to amphibian and reptiles. Pages 30-36 in: R.E. Warner and K.M. Hendrix, editors. California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley, CA.

Brookes, A. 1988. Channelized Rivers: Perspectives for Environmental Management. Wiley, Chichester, UK.

Brugam, R.B. 1978. Human disturbance and the historical development of Linsley Pond. Ecology 59:19-36.

Busch, D.E. and S.D. Smith. 1995. Mechanisms associated with decline of woody species in riparian ecosystems of the southwestern U.S. Ecological Monographs 65: 347-370.

Caruso, B.S. and R.C. Ward. 1998. Assessment of nonpoint source pollution from inactive mines using a watershed based approach. Environmental Management 22: 225-243.

Chang, H.H. 1988. Fluvial Processes in River Engineering. John Wiley and Sons. New York, New York.

Charbonneau, R. and G.M. Kondolf. 1993. Land use change in California, USA: nonpoint source water quality impacts. Environmental Management 17: 453-460.

*Clifford, H., T. Bergen, and S. Spear. 1996. The Geology of California. Sunbelt Publication, San Diego, CA.

Conroy, M.J. and R.R. Noon. 1996. Mapping of species richness for conservation of biological diversity: conceptual and methodological issues. Ecological Applications 6:763-773.

Committee on Characterization of Wetlands. 1995. Wetlands: Characteristics and Boundaries. National Academy Press. Washington, D.C.

Cooper, S.R. 1995. Chesapeake Bay watershed historical land use: impact on water quality and diatom communities. Ecological Applications 5:703-723.

Costanza, R., B.G. Norton, and B.D. Haskell. 1991. Ecosystem Health: New Goals for Environmental Management. Island Press. Washington, D.C.

Cushman, R.M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management 5:330-339.

D'Antonio, C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass-fire cycle, and global change. *Annual Review of Ecology and Systematics* 23: 63-87.

Davies, B.R., M. Thoms, and M. Meador. 1992. An assessment of the ecological impacts of inter-basin water transfers and their threats to river basin integrity and conservation. Aquatic Conservation: Marine and Freshwater Ecosystems 23: 833-843.

Dinius, S.H. 1987. Design of an index of water quality. Water Resources Bulletin 23: 833-843.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, San Francisco, CA.

Dynesius, M. and C. Nilsson. 1994. Fragmentation and flow regulation of river systems in the northern third of the world. Science 266:753-762.

Ehrenfeld, J.G. 1983. The effects of changes in land-use on swamps of the New Jersey pine barrens. Biological Conservation 25:353-75.

Environmental Laboratory. 1987. "Corps of Engineers wetlands delineation manual," Technical Report Y-87-1. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Evett, E. A. 1994. Effects of urbanization and land use changes on low stream flow. North Carolina Water Resources Research Institute, Report No. 284. 66 pp.

Faber, P.M., E. Keller, A. Sands, and B.M. Massey. 1989. The Ecology of Riparian Habitats of the Southern California Coastal Region: A Community Profile. U.S. Fish and Wildlife Service Biological Report 85(7.27). Washington, D.C.

*Ferren, W.R., Jr., P.L. Fiedler, R.A. Leidy, K.D. Lafferty, and L.A.K. Mertes. 1996b. Wetlands of California. Part II. Classification and Description of Wetlands of the Central California and Southern California Coast and Coastal Watershed. Madrono 43: 125-182.

*Ferren, W.R., Jr., P.L. Fiedler, R.A. Leidy, K.D. Lafferty, and L.A.K. Mertes. 1996c. Wetlands of California. Part III. Key to the Catalogue of Wetlands of the Central California and Southern California Coast and Coastal Watershed. Madrono 43: 183-233.

*Ferren, W.R., Jr., P.L. Fiedler, and R.A. Leidy. 1996a. Wetlands of California. Part I. History of Wetland Habitat. Madrono 43: 105-124.

*Findlay, C.S. and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11: 1000-1009.

Fisher, S.G., L.J. Gray, N.B. Grimm, and D.E. Busch. 1982. Temporal Succession in a Desert Stream Ecosystem Following Flash Flooding. Ecological Monographs 52: 93-110.

Frandsen, P and N. Jackson. 1993. The Impact of *Arundo donax* on Flood Control and Endangered Species. *Arundo donax* workshop proceedings. Jackson, N.E., Frandsen, P., Douthit, S. (editors). Ontario, CA.

Friedman, J.M., W.R. Osterkamp, and W.M. Lewis. 1996a. Channel narrowing and vegetation development following a Great Plains flood. Ecology 77: 2167-2181.

Friedman, J.M., W.R. Osterkamp, and W. M. Lewis. 1996b. The role of vegetation and bed level fluctuations in the process of channel narrowing. Geomorphology 14:341-351.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10: 199-214.

*Galay, V.J. 1983. Causes of river bed degradation. Water Resources Research 19: 1057-1090.

Goodwin, C.N., C.P. Hawkins, and J.L. Kershner. 1997. Riparian Restoration in the Western United States: Overview and Perspective. Restoration Ecology 5: 4-14.

Graf, W.L. 1979. The development of montane arroyos and gullies. Earth Surface Processes 4:1-14.

Graf, W.L. 1988. Fluvial processes in dryland rivers. Springer-Verlag. New York, NY.

Graf, J.B., R.H. Webb, and R. Hereford. 1991. Relation of sediment load and floodplain formation to climatic variability, Paria River drainage basin. Bulletin of the Geological Society of America 103:1405-1415.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. Bioscience 41: 540-551.

*Grimm, N.B., S.G. Fisher, and W.L. Minckley. 1981. Nitrogen and phosphorus dynamics in hot desert streams of the southwestern U.S.A. Hydrobiologia 83: 303-312.

Guralnik, D.B. and J.H. Friend. 1968. Webster's New World Dictionary of the American Language. The World Publishing Company. New York, New York.

Hadley, R.F., W.W. Emmett. 1998. Channel changes downstream from a dam. Journal of the American Water Resources Association 34:629-637.

Hamlett, J.M., D.A. Miller, R.L. Day, G.W. Peterson, G.M. Baumer, and J. Russo. 1992. Statewide GIS based ranking of watersheds for agricultural pollution prevention. Journal of Soil and Water Conservation 47: 399-404.

Hannah, L., D. Lohse, C. Hutchinson, J.L. Carr, A. Lankerani. 1994. A preliminary inventory of human disturbance of world ecosystems. Ambio 23:246-50.

*Hargis, C.D., J.A. Bissonette, and J.L. David. 1998. The behavior of landscape metrics commonly used in the study of habitat fragmentation. Landscape Ecology 13: 167-186.

Harris, R.E. 1987. Occurrence of vegetation on geomorphic surfaces in the active floodplain of a California alluvial stream. American Midland Naturalist 118: 393-405.

*Harris, R.R., R.J. Risser, and C.A. Fox. 1985. A method for evaluating streamflow discharge-plant species occurrence patterns on headwater streams. Pages 87-90 in: R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Follinott, and R.H. Harris, editors. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. U.S. Forest Service General Technical Report RM-120. Fort Collins, CO.

Hastings, A. and S. Harrison. 1994. Metapopulation dynamics and genetics. Annual Review of Ecology and Systematics 25: 167-188.

Hawkins, C.P., K.L. Bartz, and C.M.U. Neale. 1997. Vulnerability of Riparian Vegetation to Catastrophic Flooding: Implications for Riparian Restoration. Restoration Ecology 5(4): 75-84.

Hendricks, B.J. and J.P. Rieger. 1989. Description of nesting habitat for least Bell's vireo in San Diego County. Pages 285-292 in: D. L. Abel, coordinator. Riparian Systems Conference: Protection, Management, and Restoration for the 1990's. U.S. Forest Service General Technical Report PSW-110. Berkley, CA.

*Hickman, J.C. (ed) 1993. The Jepson Manual: Higher Plants of California. University of California Press, Berkeley. 1400 pp.

*Holland, R.F. 1986. Preliminary descriptions of the terrestrial natural communities of California. Unpublished report. California Department of Fish and Game, Sacramento, California. 156 pp.

Hornbeck, J.W. and W.T. Swank. 1992. Watershed ecosystem analysis as a basis for multiple-use management of eastern forests. Ecological Applications 2: 238-247.

Howarth, R.W., J.R. Fruci, and D. Sherman. 1991. Inputs of sediment and carbon to an estuarine ecosystem: influence of land use. Ecological Applications 1:27-39.

Hubbard, J.P. 1977. Importance of riparian ecosystems: biotic considerations. Pages 14-18 in: R. R. Johnson and D. A. Jones (technical coordinators). Importance, preservation, and management of riparian habitat: a symposium. U.S. Forest Service General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

*Hughes, R.M., D.P. Larsen, and J.M. Omernik. 1986. Regional reference sites: a method for assessing stream potentials. Environmental Management 10: 629-635.

Hunsaker, C.T. and D.A. Levine. 1995. Hierarchical approaches to the study of water quality in rivers. BioScience 45: 193-203.

Hupp, C.R. 1992. Riparian vegetation recovery patterns following stream channelization: a geomorphic perspective. Ecology 73: 1209-1226.

Hynes, H.B.N. 1975. The stream and its valley. Verh. Internat. Verin. Limnol. 19: 1-15.

Jahns, R.H. 1954. Geology of the Peninsular Range province, southern California and Baja California. California Division of Mines Bulletin 170: 29-52.

Johnson, A.R. 1988. Diagnostic variables as predictors of ecological risk. Environmental Management 12: 515-523.

Johnson, L.B., C. Richards, G.E. Host, and J.W. Arthur. 1997. Landscape influences on water chemistry in midwestern stream ecosystems. Freshwater Biology 37: 193-208.

*Karr, J.R. 1991. Biological integrity: a long neglected aspect of water resource management. Ecological Applications 1: 66-84.

Karr, J.R. 1995. Protecting aquatic ecosystems: clean water is not enough. Pages 7-13 in W.S. Davis and T.P. Simon, editors. Biological Assessment and Criteria: Tools for Water Resource Panning and Decision Making. Lewis Publishers, Boca Raton.

Karr, J.R. 1996. Ecological integrity and ecological health are not the same. Pages 97-109 in: P. C. Schultze, editor. Engineering Within Ecological Constraints. National Academy Press, Washington, D.C.

Karr, J.R. 1999. Defining and measuring river health. Freshwater Biology 41: 221-234.

Karr, J.R. and E.W. Chu. 1997. Biological monitoring and assessment: using multimetric indices effectively. EPA 235-R97-001. University of Washington, Seattle, WA.

Keller, E.A. 1972. Development of alluvial stream channels: a five-stage model. Geological Society of America Bulletin 83: 1531-1536

*Kershner, J.L. 1997. Setting riparian / aquatic restoration objectives within a watershed context. Restoration Ecology 5:4S: 15-24.

Klein, R. 1979. Urbanization and stream quality impairment. American Water Resources Association. Water Resources Bulletin. 15(4).

*Knopf, F.L. and F.B. Samson. 1994. Scale perspectives on avian diversity in western riparian ecosystems. Conservation Biology 8: 669-676.

*Knopf, F.L., R.R. Johnson, T. Rich, F.B. Samson, and R.C. Szaro. 1988. Conservation of riparian ecosystems in the United States. Wilson Bulletin 100: 272-284.

Knox, J.C., P.J. Bartlein, K.K. Hirschboek, and R.J. Muckenhirn. 1975. The response of floods and sediment yields to climatic variation and land use in the Upper Mississippi Valley. Institute of Environmental Studies, University of Wisconsin. Madison, WI.

Kondolf, G.M. 1997. Hungry Water: Effects of Dams and Gravel Mining on River Channels. Environmental Management 21: 533-51.

Kondolf, G.M., J.W. Webb, M.J. Sale, and T. Felando. 1987. Basic hydrologic studies for assessing impacts of flow diversions on riparian vegetation - examples from streams of the Eastern Sierra Nevada, California, USA. Environmental Management 11: 757-769.

Kondolf, G.M., J.W. Webb, M.J. Sale, and T. Felando. 1987. Basic hydrologic studies for assessing impacts of flow diversions on riparian vegetation: examples from streams of the eastern Sierra Nevada, California, USA. Environmental Management 11: 757-769.

Kovalchik, B.L. and L.A. Chitwood. 1990. Use of Geomorphology in the Classification of Riparian Plant Associations in Mountainous Landscapes of Central Oregon, USA. Forest Ecology and Management 33-4: 405-18.

Kratz, T.K., B.J. Benson, E.R. Blood, G.L. Cunningham, and R.A. Dahlgren. 1991. The influence of landscape position on temporal variability in four North American ecosystems. American Naturalist 138: 355-378.

Kuenzler, E.J. 1977. Water quality in North Carolina Coastal Plain streams and effects of channelization. Water Resources Research Institute Report No. 127. University of North Carolina, Raleigh, NC.

Kuenzler E.J. 1986. Land use and nutrient yields of the Chowan River watershed. Pages 77-107 in: Correll, D. L., editor. Watershed Research Perspectives. Smithsonian Institution Press, Washington, DC.

Ladson, A.R., J.W. Lindsay, J.A. Doolan, B.L. Finlaysons, B.T. Hart, P.S. Lake, and J.W. Tilleard. 1999. Development and testing of an index of stream condition for waterway management in Australia. 41:453-468.

*Lammert, M. and J.D. Allan. 1999. Assessing biotic integrity of streams: effects of scale in measuring the influence of land use/cover and habitat structure on fish and macroinvertebrates. Environmental Management 23:257-70.

La Polla, V.N. and G.W. Barrett. 1993. Effects of corridor width and presence on the population dynamics of the meadow vole *Microtus pennsylvanicus*. Landscape Ecology 8: 25-37.

Ligon, F.K., W.E. Dietrich, W.J. Trush. 1995. Downstream ecological effects of dams. BioScience 45:183-92.

Lee, L.C., M.C. Rains, J.A. Mason, and W.J. Kleindle. 1997. Peer Review Draft Guidebook to Hydrogeomorphic Functional Assessment of Riverine Waters/Wetlands in the Santa Margarita Watershed.

Leibowitz, S.G., B. Abbruzzese, P.R. Adamus, L.E. Hughes, J.T. Irish. 1992. A Synoptic Approach to Cumulative Impact Assessment: A Proposed Methodology. EPA/600/R-92/167. US Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.

Leibowitz, S.G. and J.B. Hyman. 1999. Use of scale invariance in evaluating judgment indicators. Environmental Monitoring and Assessment 58: 283-303.

*Leopold, L.B. 1994. A View of the River. Harvard University Press. Cambridge, MA

Lichvar R, Ericsson M. 2003. Planning Level Delineation and Geospatial Characterization of Aquatic Resources for Otay Watershed, San Diego County, California. U.S. Army Corps of Engineers Engineering and Research Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH. Draft Final Report to U.S. Army Corps of Engineers, Los Angeles District, Regulatory Branch.

Los Angeles District Corps of Engineers, Regulatory Branch. 1999. Scope of Work, Special Area Management Plan San Diego Creek, San Juan Creek, and Portions of San Mateo Creek Watersheds, Orange County, California.

Lotspeich, F.B. and W.S. Platts. 1982. An integrated land-aquatic classification system. North American Journal of Fisheries Management 2: 138-149.

Machtans, C.S., M.A. Villard, and S.J. Hannon. 1996. Use of riparian buffer strips as movement corridors by forest birds. Conservation Biology 10: 1366-79.

Malanson G.P. 1993. Riparian Landscapes. Cambridge University Press, New York, NY.

McCann, J.M. 1999. Before 1492. The making of pre-Columbian landscapes. Part II: the vegetation, and implications for restoration for 2000 and beyond. Ecological Restoration 17: 107-119.

Meyer, W.B. and B.L. Turner, II. 1992. Human population growth and global land-use/cover change. Annual Review of Ecology and Systematics 23:39-61.

Miltner, R.J. and E.T. Rankin. 1998. Primary nutrients and the biotic integrity of rivers and streams. Freshwater Biology 40:145-158.

Naiman, R.J., H. Decamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3: 209-12.

*Norris, R. and R. Webb. 1991. Geology of California. 2nd edition. John Wiley and Sons, New York, NY.

Olson, C. and R. Harris. 1997. Applying a two-stage system to prioritize riparian restoration at the San Luis Rey River, San Diego County, California. Restoration Ecology 5: 43-55.

Osborne, L.L. and D.A. Kovacic. 1993. Riparian vegetated buffer strips in water quality restoration and stream management. Freshwater Biology 29:243-258.

Osborne, L. and M. Wiley. 1988. Empirical relationships between land use/cover and stream water quality in an agricultural watershed. Journal of Environmental Management 26:9-27.

Perry, J. and E. Vanderklein. 1996. Water quality management of a natural resource. Cambridge, MA: Blackwell Science.

Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed - observations on the role of a riparian forest. Ecology 65: 1466-1475.

Peterjohn, W.T. and D.L. Correll. 1986. The effect of riparian forest on the volume and chemical composition of baseflow in an agricultural watershed. In: Correll, D.L. Watershed Research Perspectives. Smithsonian Institution Press. Washington, D.C.

Petersen, R.C., L.M. Petersen, and J.O. Lacoursiere. 1992. A building block model for stream restoration. In: Boon, P, Petts, and P. Callow, editors. The Conservation and Management of Rivers. John Wiley and Sons, Chichester, UK.

Petts, G.E. 1996. Water allocation to protect river ecosystems. Regulated Rivers Research and Management 12: 353-65.

*Petts, G.E. 1990. The role of ecotones in aquatic landscape management. Pages 227-261 in: R.J. Naiman and H. Decamps, editors. The ecology and management of aquatic-terrestrial ecotones. UNESCO Man and the Biosphere Series, Volume 4. Parthenon Publishing Group Limited, Park Ridge, NJ.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromburg. 1997. The natural flow regimes: a paradigm for river conservation and restoration. BioScience 47: 769-784.

Power, M.E., W.E. Dietrich, and J.C. Finlay. 1996. Dams and downstream aquatic biodiversity: potential food web consequences of hydrologic and geomorphic change. Environmental Management 20: 887-95.

Power, M.E., R.J. Stout, C.E. Cushing, P.P. Harper, F.R. Hauer, W.J. Matthews, P.B. Moyle, B. Statzner, and I.R. Wais. 1988. Biotic and abiotic controls in river and stream communities. Journal of the North American Benthological Society 7: 456-79.

Rapport, D.J. 1989. What constitutes ecosystem health? Perspectives in Biology and Medicine. 33: 120-133.

Resh, V.H., A.V. Brown, A.P. Covich, M.E. Gurtz, H.W. Li, G.W. Minshall, S.R. Reice, A.L. Sheldon, J.B. Wallace, and R. Wissmar. 1988. The role of disturbance in stream ecology. Journal of the North American Benthological Society 7:433-55.

Richards, K. 1982. Rivers: Form and Process in Alluvial Channels. Methuen and Company, London, England. 358 pages.

Richards, C. and G. Host. 1994. Examining land use influences on stream habitats and macroinvertebrates: a GIS approach. Water Resources Bulletin 30:729-37.

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

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

*Rhoads, B.L. 1990. The impact of stream channelization on the geomorphic stability of an arid region river. National Geographic Research 6:157-77.

Rood, S.B. and J.M. Mahoney. 1990. Collapse of riparian popular forests downstream from dams in western prairies: probable causes and prospects for mitigation. Environmental Management 14: 451-464.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Rothrock, J.A., P.K. Barten, G.L. Ingman. 1998. Land use and aquatic biointegrity in the Blackfoot River watershed, Montana. Journal of the American Water Resources Association 34:565-81.

Rumsby, B.T. and M.G. Macklin. 1994. Channel and Floodplain Response to Recent Abrupt Climate Change: The Tyne Basin, Northern England. Earth Surface Processes and Landforms 19:499-515.

Ryan, P.A. 1991. Environmental effects of sediment on New Zealand streams: a review. New Zealand Journal of Marine and Freshwater Research 25:207-21.

Schubauer-Berigan, M.K., M. Smith, J. Hopkins, and S.M. Cormier. 2000. Using historical biological data to evaluate status and trends in the Big Darby Creek watershed (Ohio, USA). Environmental Toxicology and Chemistry 19: 1097-1105.

Schumaker, N.H. 1996. Using landscape indices to predict habitat connectivity. Ecology 77: 1210-1225.

Scrimgeour, G.J. and D. Wicklum. 1996. Aquatic ecosystem health and integrity: problems and potential solutions. Journal of the North American Benthological Society 15: 254-261.

Sedell, J.R. and K.J. Luchessa. 1981. Using the historical record as an aid to salmonid habitat enhancement. Paper presented at American Fisheries Society Symposium Proceedings: Acquisition and Utilization of Aquatic Habitat Inventory Information.

Sedgwick, J.A. and F.L. Knopf. 1991. Prescribed grazing as a secondary impact in a western riparian floodplain. Journal of Range Management 44: 369-374.

*Shankman, D. and S.A. Samson. 1991. Channelization Effects on Obion River Flooding, Western Tennessee. Water Resources Bulletin 27:247-54.

Sher, A.A., D.L. Marshall, and S.A. Gilbert. 2000. Competition between native Populus deltoides and invasive Tamarix ramosissima and the implications for reestablishing flooding disturbance. Conservation Biology 14: 1744-1756.

Simberloff, D, J.A. Farr, J. Cox, and D.W. Mehlman. 1992. Movement corridors: conservation bargains or poor investments. Conservation Biology 6:493-504.

Smith, R.D., A. Ammann, C. Bartoldus, M.M. Brinson. 1995. An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and

Functional Indices. Wetlands Research Program Technical Report WRP-DE-9. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Smith, R.D. 2000a. Assessment of Riparian Ecosystem Integrity In the San Juan/San Mateo Creek Watersheds, Orange County, California. Final Report to the U.S. Army Corps of Engineers, Los Angeles District.

Smith, R.D. 2000b. Assessment of Riparian Ecosystem Integrity In the San Juan/San Mateo Creek Watersheds, Orange County, California. Final Report to the U.S. Army Corps of Engineers, Los Angeles District.

Smith, R.D. 2003. Assessment of Riparian Ecosystem Integrity: San Jacinto and Upper Santa Margarita River Watersheds, Riverside County, California. U.S. Army Engineer Research and Development Center, Waterways Experiment Station, Vicksburg, MS. Final Report to the U.S. Army Corps of Engineers, Los Angeles District.

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

Statzner, B., H. Capra, L.W.G. Higler, and A.L. Roux. 1997. Focusing environmental management budgets on non-linear systems responses: potential for significant improvements to freshwater ecosystems. Freshwater Biology 37:463-472.

Strahler, A.N. 1952. Hypsometric (area-altitude) analysis of erosional topography. Bulletin of the Geological Society of America 63: 1117-1141.

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38: 913-920.

Stromberg, J.C. and D.C. Patten. 1990. Riparian vegetation instream flow requirements: a case study from a diverted stream in eastern Sierra Nevada. Environmental Management 14: 185-194.

Stromberg, J.C. and D.C. Patten. 1991. Instream flow requirements for cottonwoods at Bishop Creek, Inyo County, California. Rivers 2: 1-11.

Suter, G.W. 1993. A critique of ecosystem health concepts and indexes. Environmental Toxicology and Chemistry 12: 1533-1539.

Taylor, D.W. 1982. Eastern Sierra riparian vegetation: ecological effects of stream diversions. Mono Basin Research Group Contribution Number 6.

The Nature Conservancy. 1998. Indicators of Hydrologic Alteration. Smythe Scientific Software, Fort Collins, CO.

Trimble, S.W. 1997. Contribution of stream channel erosion to sediment yield from an urbanizing watershed. Science 278:1442-1444.

U.S. Fish and Wildlife Service. 1980. Ecological Services Manual (101-104 ESM). Division of Ecological Services. USDI Fish and Wildlife Service, Washington, D.C.

U.S. Geological Survey. 1990. Land use and land cover digital data from 1:25,000 and 1:100,000 scale maps. U.S. Geological Survey Data Users Guide 4. Reston, VA. 33 pages.

Vought, L.M. B., J. Dahl, C.L. Pederson, and J.O. Lacoursiere. 1994. Nutrient retention in riparian ecotones. Ambio 23: 342-348.

Wang, L.Z., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. Fisheries 22: 6-12.

Warren, C.E. 1979. Toward classification and rationale for watershed management and stream protection. U.S. Environmental Protection Agency, EPA-600/3-79-059. 143 pages.

Wear, D.N., M.G. Turner, and R.J. Naiman. 1998. Land cover along an urban-rural gradient: implications for water quality. Ecological Applications 8: 619-630.

Wilber, D.H., R.E. Tighe, and L.J. Oneil. 1996. Associations between changes in agriculture and hydrology in the Cache River Basin, Arkansas, USA. Wetlands 16:366-78.

Williams, G.P. 1978. Bankfull discharge of rivers. Water Resources Research 14: 1141-1154.

Williamson, R.B., R.K. Smith, and J.M. Quinn. 1992. Effects of riparian grazing and channelization on streams in Southland, New Zealand. 1. Channel form and stability. New Zealand Journal of Marine and Freshwater Research 26: 241-58

* Bibliographic materials not cited in the text

Appendix 1: ArcView Files and Spreadsheet Information

Spatial information collected and utilized for spatial analysis during the project was collected and saved as an ArcView shape files. All shape files images are in NAD83, State Plane CA Zone 6, and units of feet. The U.S. Army Corps of Engineers – Los Angeles District Regulatory Branch is responsible for distribution of this information.

The ArcView GIS information for the Otay watershed was organized as follows:

ArcView Shape File Folder (c:\otay av shape files)

local drainage.shp – Riparian reach local drainage boundaries
mainstems and tributaries.shp – Mainstem and blue line tributary channels
riparian ecosystems.shp – Riparian ecosystems
land use.shp – Land Use/Land Cover (modified SANDAG 2000 LULC)
lichvar nonwetland waters.shp – Non-wetland waters (developed by R. Lichvar)
lichvar aquatic resources.shp – Aquatic resources (developed by R. Lichvar)
habitat indices.shp – Habitat integrity indices for all riparian reaches
hydro indices.shp – Hydrologic integrity indices all riparian reaches
water quality indices.shp – Water quality integrity indices all riparian reaches

ArcView Image Files (c:\otay av images)

otay 1.tif – aerial photo of portion of Otay watershed
otay 2.tif – aerial photo of portion of Otay watershed
otay 3.tif – aerial photo of portion of Otay watershed
otay 4.tif – aerial photo of portion of Otay watershed
otay 5.tif – aerial photo of portion of Otay watershed
otay 6.tif – aerial photo of portion of Otay watershed
image alignment.shp – shape file for aligning aerial photographs
otay drg.tif – digital raster graphic of Otay watershed

Information on indicators collected during baseline fieldwork and the manipulation performed in the analysis of baseline information was done in a Microsoft Excel spreadsheet. This spreadsheet can be found in the “c:\otay spreadsheet” folder on the distribution CD.

Appendix 2: Glossary

Aquatic Resources

All waters and water habitats including lakes, ponds, streams, rivers and adjoining riparian areas that they affect, marshes, vernal pools, seeps, flats, and other wetlands.

Buffer (area, zone, or habitat)

An intervening upland area or other form of barrier that separates wetlands or streams from developed or disturbed areas and reduces the impacts on the wetlands that may result from human activities. The critical functions of a buffer (associated with an aquatic system) include shading, input of organic debris and coarse sediments, uptake of nutrients, stabilization of banks, interception of fine sediments, storm-flow attenuation during high water events, protection from disturbance by humans and domestic animals, maintenance of wildlife habitat, and room for variation of aquatic system boundaries over time due to hydrologic or climate effects.

Channel

A natural stream or river, or an artificial feature such as a ditch or canal that exhibits features of bed and bank, and conveys water primarily unidirectional and down gradient.

Channel Type

Channel type refers to the Rosgen (1996) classification of streams that is based on channel slope, sinuosity, entrenchment, width to depth ratios, and channel substrate.

Clean Water Act

The federal law that establishes standards and procedures for limiting the discharge of fill and pollutants into waters of the United States.

Compensatory Mitigation

The restoration, creation, and preservation of wetlands and/or other aquatic resources for the purpose of compensating for adverse impacts on an aquatic resource caused by a permitted project or activity.

Creation

The conversion of a persistent, non-aquatic site into an aquatic site. For the purpose of this plan, creation includes the conversion of sites that currently do not meet the definition of wetlands, even though these sites were wetlands prior to being permanently drained and/or covered by fill.

Delineation

The process for determining the jurisdictional boundary of a wetland or other aquatic site.

Discharge

The placement of dredge or fill material into waters of the United States, including wetlands, that may result in impacts to the aquatic system. Examples include the re-deposition of material during excavation, mechanized land clearing, and ditching.

Enhancement

Improving existing functions of a low-quality or degraded aquatic resource or wetland.

Ephemeral

Ephemeral streams are defined as streams in which flow is attributable only to surface water runoff in response to precipitation.

Fill Material

Material taken from an upland site and used to change the bottom features of waters of the United States (includes soil, rock, vegetative material, debris, construction materials).

Floodplain

The land adjacent to a stream or lake, composed of alluvium and subject to repeated flooding.

Functional Assessment

The process by which the capacity of a wetland to perform a function is measured.

Geomorphic

A term referring to the shape of the land surface.

General Permit

A permit for a specific class of activities with minimal individual and cumulative impact within a specified area issued by the Corps, authorizing the discharge of dredged or fill material into waters of the United States, including wetlands.

Habitat Conservation Plan (HCP)

A program of the U.S. Fish and Wildlife Service (Federal) designed to offset any harmful effects that a proposed activity might have on federally listed threatened and endangered species. The HCP process allows development to proceed while providing for the conservation of species and their habitat, and provisions for incidental take

Hydrogeomorphic Wetland Class

A method of categorizing wetlands based on their hydrologic and geomorphic characteristics. The five basic hydrogeomorphic classes of wetlands include riverine, depression, fringe, slope, and flat.

In-kind Mitigation

Mitigation that results in wetlands or other aquatic resources of the same habitat type that provide similar functions and values of those removed.

Intermittent Stream

Intermittent streams are defined as streams in which groundwater-maintained base flow occurs intermittently at different times of the year

Individual Permit

A Section 404 permit issued by the Corps for an individual project for which a specific review was conducted.

Jurisdictional Wetlands

Areas that meet the soil, vegetation, and hydrologic criteria described in the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory 1987).

Mitigation

Actions or project design features that reduce impacts on wetlands by avoiding, minimizing, or compensating for adverse effects.

Mitigation Banking

Use of a single site, suitable for wetlands enhancement, restoration, and/or creation, for the mitigation of impacts on wetlands that result from more than one project at other sites.

Mitigation Sequencing

Provisions in the EPA Section 404(b)(1) Guidelines (40 CFR 230.10) and the 1990 Corps/EPA MOA requiring avoidance and minimization of adverse impacts on the aquatic environment before compensatory mitigation may be considered.

Multi-Species Conservation Program

A program of the California Department of Fish and Game (State) and U.S. Fish and Wildlife Service that takes a broad-based ecosystem approach to planning for the protection and perpetuation of biological diversity. The MSCP process identifies and provides for the regional or area-wide protection of plants, animals, and their habitats, while allowing compatible and appropriate economic activity. The primary objective of the MSCP program is the conservation of natural communities at the ecosystem scale while accommodating compatible land uses.

Nationwide Permit

General permit issued nationally for specific types of activities resulting in discharges of dredge or fill material into waters of the United States with minimal individual and cumulative impacts. Prior authorizations for Nationwide permits have been issued for several categories of activities including wetland restoration projects, maintenance of existing facilities, road crossings, bank protection, and fills 3 acres or less in size in the headwaters of watersheds. Existing Nationwide permit authorizations typically allow less than 0.5-acre impacts.

Perennial Stream

Perennial streams are defined as streams in which base flow is maintained year round by groundwater

Reference Wetland

A wetland or one of a group of wetlands within a relatively homogeneous biogeographical region that represents the variation that occurs within the type because of natural or human-induced causes.

Restoration

Actions taken which result in the re-establishment of aquatic site structure, processes, and functions in areas where the aquatic site has been altered, degraded, or destroyed.

Stream Type

Stream type refers to the Rosgen (1996) classification of streams, which is based on channel slope, sinuosity, entrenchment, width to depth ratios, and channel substrate.

Section 404 Permit

The permit issued by the Corps under Section 404 of the Clean Water Act for authorizing the discharge of dredged or fill material into waters of the United States, including wetlands; also known as Corps permit, fill permit, Department of the Army permit, DA permit, individual permit, 404 permit.

Section 404 (b)(1) Guidelines

Substantive regulations promulgated at 40 CFR 230 in accordance with Section 404(b)(1) of the Clean Water Act that provide the standards for unacceptable adverse impacts on waters of the United States, including wetlands, used to determine whether a Section 404 permit should be issued. Generally, discharges of fill are allowed under the Guidelines only if no other environmentally less damaging practicable alternative is available, no significant degradation of the waters, no adverse impacts to threatened and endangered species, and if appropriate and practicable steps have been taken to sequentially avoid, minimize and mitigate adverse impacts on the aquatic ecosystem.

Valley Type

Valley type refers to the Rosgen (1996) classification of valleys, which is based on valley slope, width, and shape.

Waters of the United States (WoUS)

Water bodies that are regulated under Section 404 of the Clean Water Act. It is the broadest category of regulated water bodies and includes wetlands along with non-wetland habitats, such as streams, rivers, lakes, ponds, bays, and oceans.

Watershed

A geographical area that drains to a major water body such as a river, lake, or creek, which is usually the water body for which the basin is named.

Wetland

Areas inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.