Recovery Potential Metrics
Summary Form

Indicator Name: CHANNELIZATION

Type: Stressor Exposure

Rationale/Relevance to Recovery Potential: Channelization is a major modification of natural form that results in habitat simplification and reduction in frequency of specific, life-supporting habitat types (e.g. pools, spawning gravels). The process also destabilizes erosion/deposition dynamics, shortens residence time during which excess nutrients may be processed, and increases risks of downstream erosion and channel destabilization with accompanying loss of use or property. Negative impacts on biological communities are well documented not only within channelized reaches but at substantial distances downstream. The significance of this metric in reducing recovery potential is based on multiple effects: degraded habitat, altered primary physical processes, destabilized instream conditions, persistence of negative effects for decades, and high expense of reengineering channel sinuosity.

How Measured: The simplest manner of measuring channelization is as the percent of total impaired segment length that is artificially straightened, as observable on imagery or mapped media. Additional measurements may choose to consider the channelized length per watershed area, whether lined or armored banks or bed are present, and percent of channelized length weighted by Strahler stream order. A visual inspection of these data is the best way to identify presence/absence of channelization, after which measurement of length channelized and impaired 303(d) reach length can be carried out via GIS to obtain the % channelized and total channelized length. Simple equal-interval quantiles of % and/or total length are appropriate for comparing among waters.

Geo-Spatial Data Source: Except on very short reaches or the smallest channel orders, channelization is visible on high resolution surface hydrography data such as data available through the National Hydrography Dataset (See: http://nhd.usgs.gov/data.html) or local resources. Manual visual interpretation from GIS hydrographic data, although somewhat laborious, is effective for identifying and measuring the length/percent of channelized reaches in each impaired waterbody segment. Channelization presence/absence may be reported as a cause for 303d listing and available as attribute data from EPA data systems (See: http://www.epa.gov/waters/ir/) .

Indicator Status (check one or more)
______ Developmental concept.
___x__ Plausible relationship to recovery.
______ Single documentation in literature or practice.
___x__ Multiple documentation in literature or practice.
______ Quantification.

Comments: Operational. Relevant across flowing watercourses in all regions. Automating this measurement may be possible and worthwhile due to its widespread occurrence and significant negative influence on recovery potential.

Examples from Supporting Literature (abbrev. citations and points made):

- (Brooks et al 2002) Loss of habitat heterogeneity is generally considered to be one of the most serious problems threatening the persistence of natural communities (Bell et al.

1991; Pickett et al. 1996; Dobson et al. 1997). The damming and straightening of stream channels have reduced spatial and temporal variability in flow (Ligon et al. 1995; Poff 1997; Graf 1999). Within stream reaches, the removal of physical structures such as woody debris or beaver dams has eliminated important types of stream habitat (Naiman et al. 1986; Frissell & Nawa 1992; Shields & Smith 1992). Despite this, we were unable to distinguish differences in community structure between high and low habitat heterogeneity treatments. Power analysis indicated that macroinvertebrate populations were more sensitive to individual site conditions at each riffle than to the heterogeneity treatments, suggesting that increasing habitat heterogeneity may be an ineffective technique if the restoration goals are to promote macroinvertebrate recovery in denuded streams. These results do not support our prediction that the recovery of stream invertebrate community structure is influenced by physical habitat heterogeneity. ... we were unable to reject or accept our initial hypothesis that increasing habitat heterogeneity would lead to faster recovery of invertebrate populations. [study done at riffle scale not reach scale; hi variability, fugitive and mobile taxa confound results, suggest not that hetero is unimportant but that it is weakly correlated with benthos in particular at the very fine scale.]

- (Freeman et al., 2007) Channelization, diversion through pipes (‘‘piping’’), impoundment and burial of headwater streams unavoidably impact stream systems by altering runoff patterns, fluxes to downstream segments, and by eliminating distinctive habitats (8).
- (Sondergaard and Jeppesen 2007) Structures placed along lakes and rivers to prevent erosion, and channel engineering to increase navigation depths are, at least in some river systems, considered key factors for the apparent increase in flooding disturbance events over recent decades (Kundzewicz *et al*. 2005; Pinter *et al*. 2006). Channelization and reduced flooding of lowland areas along rivers influence the retention of nutrients, and restoration by allowing water to spill back onto the original floodplain can be a way of increasing the retention of both nitrogen (Sheibley, Ahearn & Dahlgren 2006) and phosphorus (Kronvang *et al*. 2007) (1091).
- (Gregory et al. 2002) Interactions of geomorphic and hydrologic processes shape river channels through both erosional and depositional processes that occur during floods that fill the active channel and extend across river floodplains. If large floods are eliminated by dams, channels can incise and impede interaction with their floodplains. In the Willamette River in Oregon, more than 50% of the channel complexity has been reduced through active channel alteration, bank hardening, and hydrologic alteration through flood control (figure 2; Gregory et al. 2002) (715).
- (Pegg et al., 2003) Altered flow has been one of the primary consequences of impoundment and channelization. Impoundments designed primarily for flood control, navigation, and water supply tend to dampen natural flow variation by storing large amounts of water for later, controlled release (Bravard and Petts, 1996). Conversely, dams built for power generation tend to accentuate natural variability by creating daily high and low flow periods to meet electrical demands (Bravard and Petts, 1996). Channelization, accomplished by armoring the shorelines, diverting water out of side channels, and straightening the channel, also influences flow by facilitating rapid transport of water downstream. Other direct consequences of channelization include loss of river connectivity to the floodplain (Ward and Stanford, 1995), changes in water quality (Whitley and Campbell, 1974), and loss of aquatic habitat (Mosley, 1983).

  Flow in many large river systems is affected by a combination of alterations, including impoundments, channelized reaches, water diversions, and numerous landscape changes in the catchment. These alterations are likely to result in complex changes to the flow regime, and the precise nature of these changes may be difficult to predict. Many factors including flow reduction in impounded reaches, increased velocities in channelized reaches, loss of diverse habitat complexes, changes in runoff and sedimentation loading rates, and altered nutrient cycles, all a result of human alteration, create an environment seldom if ever historically experienced by the native fauna in these lotic systems (Ligon et al., 1995; Ibanez et al., 1996) (63-64).

- (Wall et al.,2004) Decline of this species has been attributed to habitat deterioration caused by siltation, channelization, and impoundments and predation by stocked fish (Tabor 1998; Schrank et al. 2001) (955).
- (Pringle 2001) Effects of the isolation of upper watersheds on biological integrity are not well understood. Modifications of lower watersheds such as water extraction, channel modification, land-use changes, nutrient discharge, and toxic discharge can initiate a cascade of events upstream that are often not immediately associated with these original downstream sources of disturbance (Pringle 1997) (987).
- (Paul and Meyer 2001) The major impact of urbanization on basin morphometry is an alteration of drainage density, which is a measure of stream length per catchment area (km/km2). Natural channel densities decrease dramatically in urban catchments as small streams are filled in, paved over, or placed in culverts (Dunne & Leopold 1978, Hirsch et al. 1990, Meyer & Wallace 2001). However, artificial channels (including road culverts) may actually increase overall drainage densities, leading to greater internal links or nodes that contribute to increased flood velocity (Graf 1977, Meyer & Wallace 2001) (338).
- (Paul and Meyer 2001) Introduced fish species are also a common feature of urban streams. As a result of channelization, other river transportation modifications, and voluntary fisheries efforts in the Seine around Paris, 19 exotic species have been introduced, while 7 of 27 native species have been extirpated (Boet et al. 1999). The red shiner (*Cyprinella lutrensis*), a Mississippi drainage species commonly used as a bait fish, has invaded urban tributaries of the Chattahoochee River in Atlanta, Georgia where it has displaced native species and now comprises up to 90% of the fish community (DeVivo 1995) (353).
- (Paul and Meyer 2001) Changes in sediment supply may also alter channel pattern. Increased sediment supply during construction has converted some meandering streams to braided patterns or to straighter, more channelized patterns (Arnold et al. 1982). In the latter case, channelizing leads to increased slope and therefore higher in-stream velocities, especially where artificial channel alteration is carried out to increase the efficiency of the channel in transporting flows (Pizzuto et al. 2000).

  Urbanization can also alter sediment texture. Less fine sediment, increased coarse sand fractions, and decreased gravel classes have been observed in urban channels as a result of alteration of sediment supply and altered velocities (Finkenbine et al. 2000, Pizzuto et al. 2000). In addition to sediment changes, large woody debris is also reduced in urban channels. Catchments in Vancouver, British Columbia with greater than 20% ISC generally have very little large woody debris, a structural element important in both the geomorphology and ecology of Pacific Northwest stream ecosystems (Finkenbine et al. 2000).

  Other geomorphic changes of note in urban channels include erosion around bridges, which are generally more abundant as a result of increased road densities in urban channels (Douglas 1974). Bridges have both upstream and downstream effects, including plunge pools created below bridge culverts that may serve as barriers to fish movement. Knickpoints are another common feature of urban channels. These readily erodeable points of sudden change in depth are created by channel erosion, dredging, or bridge construction and are transmitted throughout the catchment, causing channel destabilization (Neller 1988). Other features include increased tree collapse, hanging tributary junctions as a result of variable incision rates, and erosion around artificial structures (e.g., utility support pilings) (Roberts 1989).

  Changes in the hydrology and geomorphology of streams likely affect the hydraulic environment of streams, altering, among other things, the velocity profiles and hyporheic/parafluvial dynamics of channels. Such changes would affect many ecological processes, from filter-feeding organisms (Hart&Finelli 1999) to carbon processing and nutrient cycling (Jones & Mulholland 2000) (340-341).
- (Light and Marchetti 2007) Quantitative analyses of native fish declines, invasions, and habitat alteration in this region reveal that dams, channelization, and water pollution are associated with both native species decline and with the richness and abundance of

introduced fishes (Aparicio et al. 2000; Corbacho & S´anchez 2001; Clavero et al. 2004) (443).

- (Novotny et al., 2005) The models [for assessing ecological integrity] (functions) link the individual risks and consider their synergy, addictivity, or antagonism. The risks include:
    (1) Pollutant (chemical) risks, acute and chronic, in the water column
        Key metrics: Priority (toxic) pollutants, DO, turbidity (suspended sediment), temperature, pH.
    (2) Pollutant risk (primarily chronic) in sediment
        Key metrics: Priority pollutants, ammonium, DO in the interstitial layer (anoxic/anaerobic or aerobic), organic and clay content.
    (3) Habitat degradation risk
        Key metrics: Texture of the sediment, clay and organic contents, embeddedness, pools and riffle structure, bank stability, riparian zone quality, channelization and other stream modifications.
    (4) Fragmentation risk
        Key metrics:
        Longitudinal—presence of dams, drop steps, impassable culverts.
        Lateral—Lining, embankments, loss of riparian habitat (included in the habitat evaluation), reduction or elimination of refugia.
        Vertical—lack of stream-groundwater interchange, bottom scouring by barge traffic, thermal stratification/heated discharges, bottom lined channel (190).
- (Pegg et al., 2003) Visual inspection of Figure 2 indicates that flows in the middle reaches of the river (i. e., the interreservoir zone and the upper portions of the channelized zone) have changed dramatically between the pre- and post-alteration periods as evidenced by a decrease in flow variability during the post-alteration period. In contrast, flow variability has maintained some integrity between the two periods at Fort Benton (i.e., unaltered zone), the upper most gauge, and Hermann (i.e., channelized zone), the lower most gauge on the Missouri River (Figs. 1 and 2) (66).
- (Pegg et al., 2003) As with mean flows (Fig. 2), the amount of variability in the residual plots is lower after alteration in the inter-reservoir and upper channelized zones of the river as represented by Bismarck, ND, and Omaha, NE (Fig. 3). Conversely, in the extreme upper and lower gauges on the river, residual variability is similar in pre- and post-alteration periods.

  Daily mean flows were significantly higher during the post-alteration period at all gauges ($P < 0.10$; Table 1). Post-alteration daily flows averaged 16% higher than the pre-alteration flows at Bismarck, ND, and 10% higher at Yankton, SD (Table 1). The remaining gauges had daily mean flows during the post-alteration period that averaged from 30 to 45% higher than pre-alteration flows (66).