IX. ECOLOGICAL CONSIDERATIONS

9.1 General

Ecological considerations are important for the proper design, construction, maintenance and/or removal of diversions.

The following discussion provides criteria and guidelines for evaluating factors influencing the ecological environment of a mining area. First, water quality and physical characteristics are described (Soil Conservation Service, 1977), then stream study and investigation procedures are briefly considered and finally recommended reconstruction techniques and considerations are given and the potential short- and long-term effects of diversion structures are evaluated.

9.2 Water Quality

Water quality is a limiting factor for fish production and is an important element in determining the biological community. The following items affect fish species suitability, production, and survival.

1. Temperature is an important physical factor. Summer water temperatures commonly vary as much as 10° in a 24-hour period. In general, summer temperatures should be between 50° and 70° for cold-water species. Egg hatching success is best for trout between 45° and 55°. Warm-water species need summer temperatures between 70° and 90°.

   Removal of shade tends to raise water temperatures while the maintenance of vegetation for shade may keep the water cooler. Water temperatuare is raised when velocity and depth are reduced. Water temperature may be affected by release of water from upstream impoundments.

2. Turbidity caused by inorganic material, such as clay, is detrimental to fish production. Such material destroys spawning areas by sedimentation and reducing growth of bottom organisms. Adult fish generally can withstand high levels of turbidity for short periods of time, but prolonged exposure may cause mortality.

It is reported that turbidity as high as 245 mg/l is not harmful to fish. In fact, fish thrive in water with turbidities that range over 400 mg/l and average 200 mg/l. Turbidities of 3,000 mg/l are considered dangerous to fish when maintained over a ten-day period. Trout eggs were destroyed with 2,000 mg/l turbidity for six days. Symptoms of fish stress appear as turbidity approaches 20,000 mg/l; death between 50,000 and 200,000 mg/l. At turbidities causing death, the opercular cavities were found to be matted with soil and the gills had a layer of soil in them.

3. Oxygen requirements for subsidence of fingerling and adult salmon and trout are about 6 ppm dissolved oxygen. Incubating eggs require a minimum of 8 ppm. Warm-water species require about 3 ppm. Water at or near oxygen saturation, for its temperature and elevation, is always satisfactory. Oxygen is put into water by direct absorption from the atmosphere, photosynthesis of growing plants, and by tumbling action of stream or waterfalls and turbulence generated at drop inlets or drop spillways. Turbidity, reduced flow, and nontumbling action reduce oxygen.

4. Carbon dioxide is another of the basic factors determining productivity of waters. It is necessary in photosynthesis and for keeping minerals, such as calcium, in solution. High carbon dioxide levels reduce the ability of fish to take up oxygen and to dispose of carbon dioxide from the body. Concentrations of carbon dioxide should be kept below 25 ppm.

   Carbon dioxide is put in water by direct absorption from the atmosphere, decomposing organic matter, and respiration of plants and animals. It is removed by photosynthesis, agitation of water, evaporation, and rise of bubbles from depths.

5. pH is a measure of the acid intensity in water. The scale of reading is from 0 to 14. Optimum fish production lies between 6.5 and 8.5. Values below 5 and above 9 affect the ability of fish to take oxygen from the water source. Water pH is changed if an acid layer of soil is exposed in stream bottom or sides.

9.3 Physical Characteristics

These stream channel features affect fish production, species suitability, and survival.

1. Bottom material - The bottom material of a stream is important from the standpoint of food production and natural spawning. The following yield in grams of food per square foot in terms of different stream bottom materials has been recorded: silt - 3.07; cobble - 2.47; coarse gravel - 1.51; fine gravel - 0.93; and sand - 0.1.

   Coarse and fine gravel beds in riffles are best for trout to deposit their spawn successfully. Most warm-water fish spawn in sand or silt beds in water less than three feet deep and with little or no current.

2. Water types

a. Riffle - Section of stream containing gravel and/or rubble, in which surface water is at least slightly turbulent and current is swift enough that the surface of the gravel and cobble is kept fairly free of sand and silt.

Riffles are essential for trout spawning and food production. Riffles should occur at intervals equal to every five to seven channel widths. The current in the riffle should be swift enough to carry away sediment. The bed material in riffles should be larger than in pools so as to provide for aeration of the water. A water depth of six inches is desirable.

b. Pool - Section of stream deeper and usually wider than normal with appreciably slower current than immediate upstream or downstream areas and possessing adequate cover (sheer depth or physical condition) for protection of fish. Stream bottom usually is a mixture of silt and coarse sand.

Pools are valuable as resting and refuge areas. Some surface feeding is also done.

c. Flat - Section of stream with current too slow to be classed as riffle and too shallow to be classed as a pool. Stream bottom usually composed of sand and finer materials with coarse cobbles, boulders, or bedrock occasionally evident.

d. Cascades or bedrock - Section of stream without pools, the bottom consisting primarily of bedrock with little cobble, gravel, or other such material present. Current usually faster than in riffles.

3. Stream side vegetation - This item pertains to the relation of vegetation to stream shade and fish shelter. Low shrubs and grasses provide shade for small streams, but do not over-shade them. Such vegetation does not clog streams by falling in the water, and it provides hiding cover for fish if allowed to hang over the bank into the water.

Trees are necessary for shade along streams over 30 feet wide since low shrubs and grasses shade only a small portion of this width.

An ideal situation, along small streams, is enough trees for aesthetic purposes and low shrubs and grasses providing shade and cover. Along large streams, trees for about 40 percent of the stream length, on both sides, should be present. There probably are situations where the presence of trees well back from the water's edge furnishes shade almost as good as comparabale ones closer to the stream. This would be true especially on the east side of north-south flowing stream and the south side of east-west streams.

4. Velocities - Tolerable water velocity for fish is governed by several factors, chiefly by the species of fish, size of fish, and the distance and frequency of resting areas. Boulders, pools, deflectors, etc. provide resting areas.

9.4 Stream Study and Investigation Procedures

The objectives of any stream study should be clearly defined prior to being undertaken. Neglect of this essential preliminary step may result in failure to obtain critical information or conversely in expenditures of needless and wasteful amounts of time, effort and money. The major objective of studies designed for stream location is to determine the biological community present within the existing streams, and conditions existing within the stream to support the community.

This will involve one or more sampling stations on the stream system. Sampling may be occasional, perhaps at weekly, monthly, or even quarterly intervals. Sampling should be designed to obtain quantitative or qualitative nature and will usually include physical, chemical and biological data.

Investigations involving the definition of a biologically active stream may necessitate the sampling of the three basic stream habitats (riffle, pool, run), if present. Study sites should be representative of the stream areas most likely to be affected or impacted by mining activity. Stream condition must be considered since unusual stream conditions such as high water can make biological sampling impractical and/or lead to erroneous conclusions based on limited or incomplete samples. Extremely low water stages can also make the results of sampling efforts of limited value. In general, in the Eastern Coal Province the greatest measurable aquatic invertebrate family diversities will be found in late spring and summer. For a long-term biological survey program it is best that collections be made at least once during each of the annual seasons.

The series approach is used to document water quality and biological changes throughout a reach of river or stream. The pattern of changing quality reflected by the relationship among the several stations is more important than the isolated biological or physiochemical quality at any one station. The assessment of the relationship among the stations therefore depends on the collection of data representative of the stream at each station.

Establishment of sites that are physically similar is desirable. However, when dissimilar sites are to be compared, care should be taken so that data comparisons do not lead to false conclusions concerning the biological communities occurring in these study sites. The establishment of one or

more control stations can allow for the comparison of water and biological quality above and below the point of alterations. A control station upstream of the source of impact is as important as the stations within or below the impact area and should be chosen with equal care to ensure representative results. The distance between the sampling sites should be sufficient to permit accurate measurement of potential changes.

Bridges should be avoided when sampling for bottom organisms. Benthic populations may have been altered or destroyed by bridge construction activities. In addition, the physical environment of the stream near bridges is often altered and may be unrepresentative of the stream in general. If sampling near a bridge is necessary, then it should be limited to the upstream side. Bridges frequently shade the stream beneath them and reduce light exposure and penetration.

A survey sheet has been included in Appendix E so that the investigator may accurately and concisely document the physical, chemical and biological properties observed at each sampling site or locality. Detailed instructions and suggestions for completing these survey sheets are also included so that some consistency might be obtained when data are recorded by the user. Individual survey sheets allow the investigator to record the precise stream conditions at each station or site at the time of survey. The field sheets can be used to document, in a comparative manner, the changes that occur from site to site at any given sample date or at one site over an extended time period. Additionally, the latest available reference on actual sampling techniques has been duplicated and placed in Appendix E for ready reference.

9.5 Reconstruction

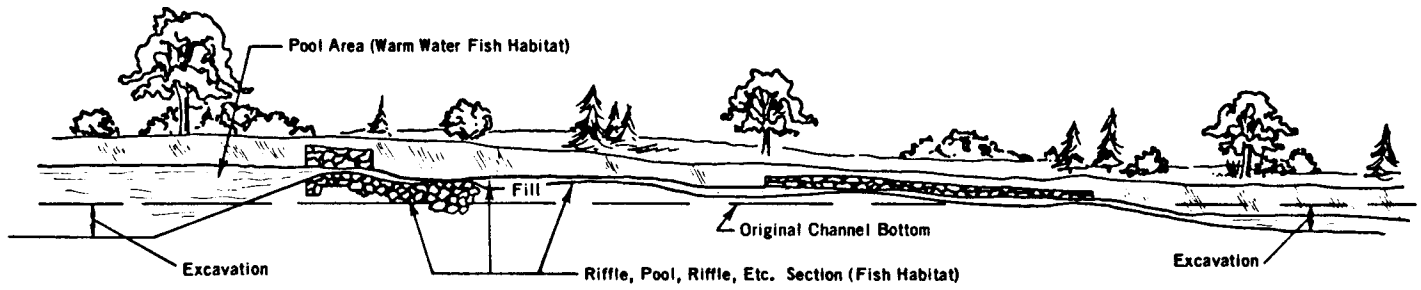
If a stream must be relocated, various stream improvement techniques may be employed to create suitable habitats for the desired fish species. Many types of devices may be installed to produce more favorable conditions for fish production. They may be classified as (1) dams, (2) deflectors, and (3) covers. Small dams may be built, creating ponds behind the dams and deep holes on the downstream side. The dams are generally constructed of logs, boulders, and rocks, or sticks and sod, depending on the stream conditions.

The ecological disadvantages of damming are: (1) the water is exposed to warming, (2) sand may fill in the pool above, and (3) fish movement may be blocked. Creation of ponds increases the space of the aquatic habitat and

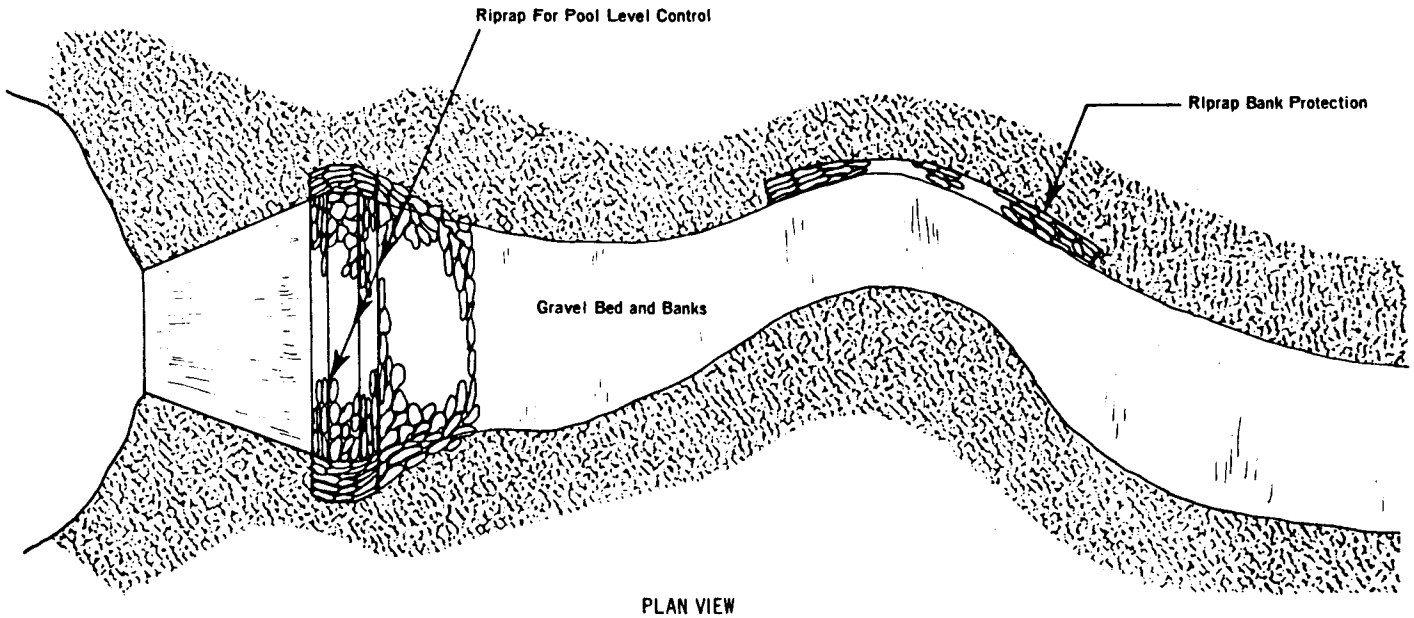
provides resting places, while formation of deep holes allows fish to survive severe winters and dry periods (Figure 9.1). Gard (1961) found that suitable trout habitat could be created by the placement of dams in a California stream. Saunders and Smith (1962) used dams, deflectors, and shelters to provide more hiding places for young trout in a stream on Prince Edward Island.

Deflectors are partial barriers which accelerate and direct the current, creating both local scour and deposition. The deflector confines the flow to a narrower channel, causing a long, deep hole to be scoured. By narrowing and deepening the channel, overheating is prevented. The accelerated current exposes the gravel substrate required for trout spawning and washes finer particles to quiet waters, where they settle. Weed beds tend to form in these silt deposits, providing food and shelter for young fish. Shetter et al. (1949) described deflectors used to improve trout habitat in a Michigan stream. He used rectangular log cribs filled with gravel, soil, and sod and anchored into the bank at a 35°-45° angle from the downstream bank. Deflectors must be strategically located and angled properly to insure that they will effectively direct the current to produce the desired scour and deposition. Various deflector designs include wing deflectors, V-deflectors, Y-deflectors, I-deflectors, A-deflectors, and underpass deflectors (Hubbs et al., 1932). Tarzwell (1937) quantified habitat improvement resulting from deflectors placed in six Michigan streams. He found the following improvements in trout habitat: (1) increased number and depth of pools, (2) increased aquatic habitat due to increased pool width, (3) exposed gravel for trout reproduction, (4) riffle areas, (5) submerged plant beds, and (6) mucky areas. The deflectors created a more diverse substrate capable of producing a larger quantity of food organisms. "Food production in a sandy section may be increased by a deflector which uncovers gravel and produces mucky areas for plant beds," (Tarzwell, 1937).

Good cover is required to offer the fish hiding places and resting places sheltered from the current. Cover devices can be designed to catch naturally drifting debris, thus enhancing their effectiveness. Undercut banks and submerged tangles of roots, brush, or limbs provide good cover. Some types of cover are especially designed to protect erodible banks as well as to provide fish cover. A boom cover is such a structure and is designed to protect the outside bank of a bend while creating fish cover. A boom cover consists of old logs and stumps floating behind a fixed log barrier and placed at the out-



CHANNEL PROFILE - BUILT IN GRADE AND BOTTOM CONFIGURATION



PLAN VIEW

Figure 9.1. Channel segment with pond, riffle, pool layout (from Soil Conservation Service, 1977).

side of a bend. Several other types of structures used for cover include the bend raft, the bank cover, log platforms, the teepee cover, bridge covers, brush shelters within the stream, and overhanging shelters. Hubbs et al. (1932) discusses the construction and use of a variety of different stream improvement devices. Planting of streamside shrubs and trees also develops stream cover and protective shade. Figure 9.2 illustrates some of these concepts.

Research has been conducted to determine the success of stream reconstruction after rechanneling a trout stream in Pennsylvania (Bradt and Wieland, 1978). Rechannelization of the stream was required following highway construction in the stream's vicinity. Reconstruction efforts included: (1) installation of gabions to narrow and deepen the bed, (2) placement of large rocks and small dams to diversify the substrate, and (3) planting of trees, shrubs, and ground cover along the banks. The authors concluded "It is possible to restore a stream after it has been rechanneled, but, even with the most intensive efforts, it will take ten to twenty years before the streambed will again be shaded. Rechannelization should be pursued only as a last resort, because of the length of the recovery time. When it is absolutely necessary to damage existing stream ecosystems it must be kept in mind the amount of time, effort, and money involved in stream restoration and the many years that must pass before the stream ecosystem will recover from the damage." (Bradt and Wieland, 1978.)

9.6 Conclusion

To conclude, if a perennial or in some cases an intermittent stream must be relocated and reconstructed, a combination of stream improvement techniques should be used to restore the stream habitat. The ecological and engineering techniques employed depend on the specific stream involved, such as the bed and bank material, winter ice conditions, flooding, and the species for which the management is being designed. Selection and placement of habitat improvement devices must be carefully planned for maximum effectiveness.

Most state game and fish agencies have guidelines for stream improvement and restoration. A partial list of references and handbooks covering this subject is given in Section 9.7.

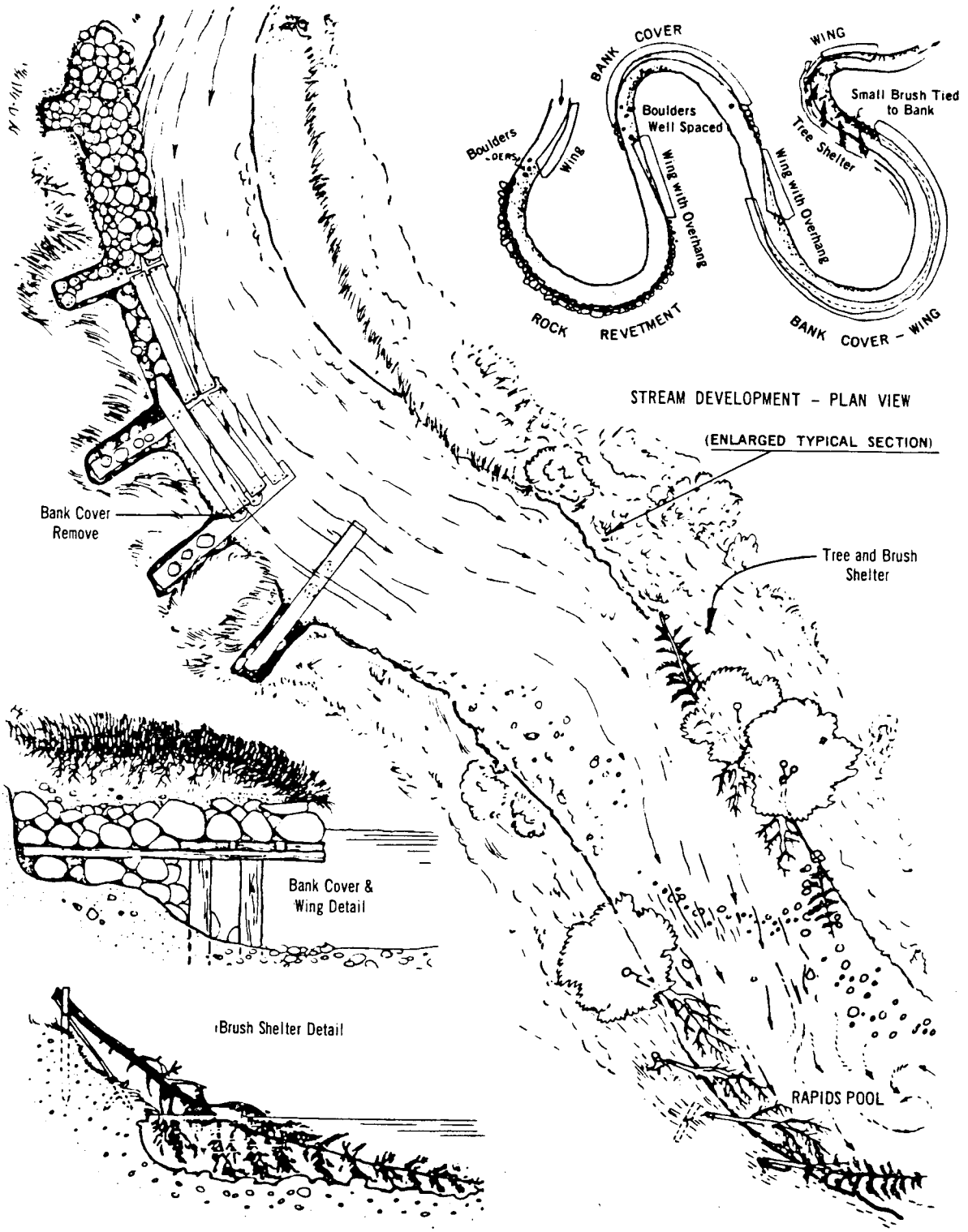


Figure 9.2. Fish habitat development (from Soil Conservation Service, 1977).

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