5. Discussion and Integration

The Salmon River watershed is comprised of many factors that affect its productivity and health. The land use, hydrology, biology and socio-economic factors are not isolated from one another but function together in a complete system. As a result of this, it is important not simply to discuss these factors independently. To look at the watershed more holistically we have chosen to discuss five different issues:

1) an ecological approach to development in the Salmon River watershed;
2) the linkages between Lake Ontario and the Salmon River watershed;
3) ecology of the watershed and its structure and function
4) regulation of the Salmon River watershed
5) human influences on the ecology of the watershed and implications for the economy

5.1. Development Within the Salmon River Watershed: an Ecological Approach

The world's population is growing at an alarming rate. With this growth comes the alteration of more natural land to support the human population. The Salmon River watershed, with its vast resources, will not remain unaffected by this growth in the future. What are the implications for increased development within the Salmon River watershed? The Oswego County Department of Planning and Development (OCDPD) states that the people of the watershed will be faced with the challenge of "maximizing the economic potential of all resources, human, natural, and manmade" (OCDPD, 2002). However, this cannot be done within the watershed unless an ecological approach to development in the area is constructed. There are many factors within the watershed that would be affected, assuming increased development, which need to be taken into account. The OCDPD identifies different factors within the watershed that are important for sound ecological development (OCDPD, 2002). Five of these factors will be discussed:

1) directing development to sites with existing infrastructure and low impact on natural resources
2) preventing decreases in ground water and maintaining water quality[1]
3) wildlife corridors
4) buffer guidelines
5) landowner conservation easements

5.1.1. Directing Sites of Development

Development within the watershed should occur in areas where there are presently facilities available. There are currently six industrial parks (IP) within Oswego County. These parks have already altered the land and should be utilized before opening

[1] Water quality is not mentioned by the OCDPD

new land for industrial development. There is a large potential for development within these existing parks. Independence IP has 70 available acres. 57 acres are available in Lake Ontario IP. Airport IP, Oswego IP and Kajac IP have 120, 220 and 195 acres available respectively. Riverview Business Park has over 100 acres available (www.oswegocounty.org/OOC_Industrial _Parks.htm).

It is critical that development does not ruin or disturb wetlands within the watershed. Wetlands are very often affected by development and support various species. Some of these species are listed as rare, threatened or endangered. A study conducted by the EPA found 2-5 aquatic/wetland species known to be at risk within the Salmon River watershed (http://www.epa.gov/iwi/hucs/04140102/score.html). Wetlands also reduce the rate and volume of storm water flowing to the surface and sink, capture and store pollutants (Davis, 2000). 5.1.2. Lowered water quality and ground water decreases

Development would directly alter the area by lowering water quality and quantity within the Salmon River watershed. Industrial, agricultural, and residential development can all diminish water quality. Industry obviously affects water quality when harmful chemicals or byproducts from manufacturing find their way to water sources, either by leaching into the groundwater or by direct emission into open bodies of water. Increased agricultural development could cause problems such as eutrophication as a result of the increased nutrients being added to the land to increase crop production. In addition, agriculture causes compaction and erosion of the soil, which may cause increased sediment load in the Salmon River and its tributaries. Presently this is not a major issue in the watershed. However, sometime in the future, more forest land will be turned into agricultural land to help feed the growing population. Then water quality problems could arise if Best Management Practices (BMPs) are not utilized in an attempt to dampen some of the issues mentioned above. Greater amounts of residential housing would decrease water quality for many reasons. One factor would be added sewage, as most of the housing in the watershed uses septic systems. Pesticides and fertilizer used in lawn care would also harm the water quality.

Water quantity will be compromised in the Salmon River Watershed with added development. This will mostly be caused by increased extraction of water from added residents' consumption, use in industrial practices, and in irrigation for agriculture. Groundwater is a large source of water within the watershed. Extraction of water would affect the Tug Hill aquifer, which runs under the Salmon River Watershed. Another force that could decrease amounts of water storage within the watershed is heightened amounts of infiltration-excess overland flow caused by development. Area that was once covered by vegetation may be replaced by pavement or structures that do not allow for water to infiltrate through the soil. This creates a deficit because groundwater will have less recharge in some areas, and there will be increased amounts of water evaporated. Lastly, if a business develops within an Empire Zone, i.e., a specific area, designated by the State for development, with special incentives to encourage business growth, they receive unlimited free water for their first three years (www.oswegocounty.org100C_EDZ.htm).

5.1.3. Wildlife Corridors

Development causes fragmentation of the landscape. This creates a problem because it isolates populations of species and creates more edge. Erecting corridors can help alleviate the problems caused by fragmentation. The probability of interchange of individuals between forest stands is increased by corridors. However, species movement across corridors is not as effective as in contiguous forest (www.safnet.org/archive/corridors501.htm).

Oswego County and Niagara Mohawk have developed the Salmon River Greenway Corridor Community Enhancement Project in response to habitat fragmentation and in response to the increasing demand for waterfront property. The county also has hopes for this area to accommodate recreation demand and offer nature education programs. However, constraints, present in this corridor and for the development of more, are the lack of public funding (OCDPD, 2002).

5.1.4. Conservation Easements

In response to the issues just mentioned and many others, it is essential for planners in the Salmon River watershed to encourage landowner conservation easements. This is especially important on waterfront property. Homeowners often have reservations about conservation easements and public parks being adjacent to their own land. Frequently residents on their private land feel that these areas would be a threat to their own rights, liability, privacy and/or safety (OCDPD, 2002). One way to attempt to remedy this situation is to foster communication between private landowners, government employees, and the public in dealing with these issues. Hopefully, this would eliminate some of the fears and make more private landowners personally willing to be involved in the preservation of the watershed they live in.

5.1.5. Buffer Zones

Buffers are vital to protecting the water quality and provide species habitat (Tickell, 1995). They perform the functions of removing pollutants before they reach the stream, stabilizing streambanks (minimizing erosion), and moderating stream temperatures (Davis, 2000). Deeper rooting plant species are most beneficial in removing pollutants and stabilization (Tickell, 1995). Buffers also provide food and habitat for species that are in the water as well as species living on the land (Davis, 2000).

There is no question that specific guidelines need to be established for the Salmon River watershed. The size and extent of a particular area's buffer zone depends on its specific characteristics. Specific studies regarding this issue in Salmon River watershed should be conducted to determine just how extensive a buffer system is needed.

The Salmon River Watershed presently is mostly undeveloped, but it will not remain this way in the future. However, development within the watershed does not have to be seen as a negative thing. The OCDPD states, "its not the resources we lack, nor even the knowledge, but the vision to use them constructively"(OCDPD, 2002). If the communication lines between people involved in the watershed are open and an ecological approach is taken, future development can actually be seen as positive within the Salmon River Watershed.

5.2. Linkage Between Lake Ontario and the Salmon River Watershed

The Great Lakes Ecosystem is composed of the open water system, shoreline systems, and ecosystems that occur in the upper watershed. These ecosystems are interrelated and interdependent each other. Here, we examine the relationship between the Great Lakes and its tributaries, especially between the Lake Ontario and the Salmon River watershed through its ecosystem.

Lake Ontario is connected to the upper watershed by the movement of surface water, groundwater and living organisms. Rivers and streams supply lakes with water and nutrients, and provide spawning and nursery areas for anadromous fishes. The tributaries, in turn, depend on upland vegetation to regulate the nutrients and solids entering the waterways, and for input of energy and material such as the autumn leaf fall.

The watershed tributary to Lake Ontario from the Niagara River to the St. Lawrence River extends over 82,880 km^2 (32,000 square miles) and around half of it lies within the U.S. Because the major river inflow is the Niagara River with a mean annual discharge of 5,720 m^3/s and the average annual precipitation over the Lake Ontario basin is about 864 mm (34 inches). Hence, the Salmon River is not a major inflow, but it is important to look at the river as a representative of tributaries, fishery and water quality in particular.

Geographically, New York's Lake Ontario drainage basin is composed of six major watersheds: LO western, central, eastern, Genesee River, Seneca-Oneida-Oswego, and Black River. Each of these major watersheds contains several sub-units. The Salmon River watershed is classified as part of the Eastern basin of Lake Ontario (Wilson 1969) but recently, it is sometimes categorized in direct drainage areas so-called the Salmon-Sandy Drainage Area (FL-LOWPA 2000), which means the importance of this watershed is increasing as a source of pollution to the Lake Ontario (LO).

The Eastern sub-basin is composed of the Salmon River watershed, Sandy Creek watershed, Wine Creek watershed, and direct discharges to the Lake (Luckey 1997). The Salmon River Watershed also has 17 different sub-basins, as determined by our GIS group, along its tributaries.

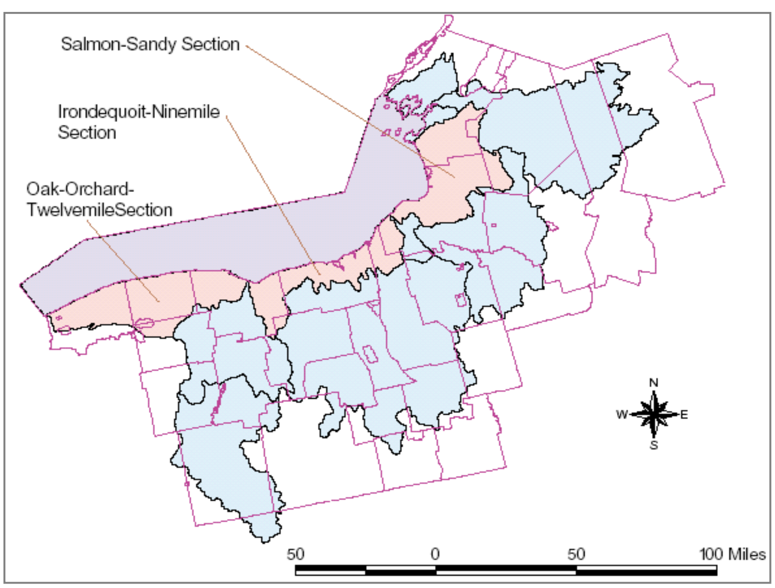


Figure 5-1. Salmon-Sandy Section (Eastern Sub-basin)

While there is no major metropolitan area, numerous small communities spread over the Direct Drainage Area basin. A variety of water related business and activities are evident along the Lake Ontario shoreline and Salmon River that provide for water-based recreation such as boating and ice sailing; trout and steelhead fishing; snow-mobiles in winter; and passive recreation such as bird watching and sightseeing throughout the watersheds.

According to the physiochemical group, most of the eastern direct drainage is part of the Lorraine Group (Table 1-1) formed a little earlier in the Middle Ordovician and the Salmon-Sandy drainage area is characterized by Oswego Sandstone, with thin red or gray shales, and Pulaski Formation, with tan-gray siltstones, shales, and light gray sandstone. As the southern part of this drainage area, the fact that the Salmon River watershed starts from the hilly slopes of the Tug Hill Plateau, the highest lands in the eastern sub-basin also overlapped with the Applachian Uplands confirms that the watershed is a part of a continuous eco-region.

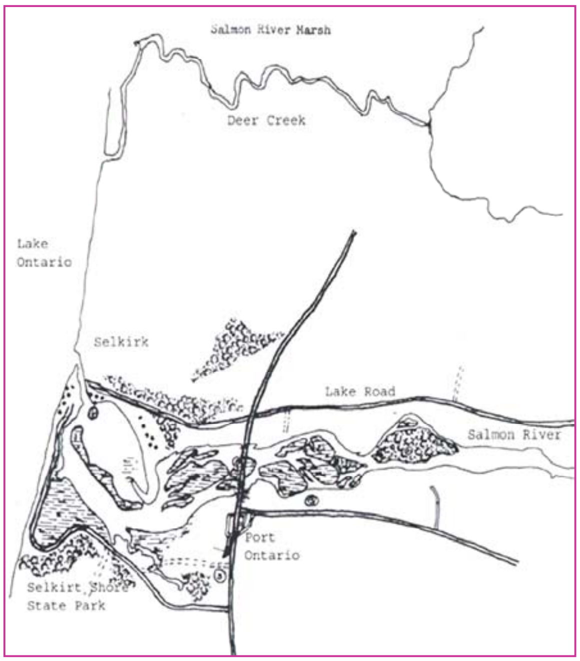


Figure 5-2. Salmon River Marsh

In terms of direct impacts on the lake, the '**Salmon River Marsh'** between the Salmon River mouth and Lake Ontario (left illustration) has played an important role of a buffer zone between the lake and the watershed. According to a map of USGS 1960s (Wilson 1969), the area of the marsh used to be over 320 acres: half of it was open water, and the other half was open marsh type of coverage, although we did not identify the marsh area adjacent when we reached the mouth of the Salmon River on our field trip. This marsh had limited waterfowl use due to heavy human activities. In the river-lake system point of view, we looked at two issues specifically: the Salmonid fishery and water quality issues.

5.2.1. The Salmonid Fishery in Lake Ontario

The Salmon River is a significant tributary in this sub-basin and a popular trout fishery. Atlantic salmon (*Salmo salar*) were once among the most important fish in the Lake Ontario and were described as being a valuable source of food because they were barred by Niagara Falls. Their abundance was believed to be a prominent factor in the early settlement of the Lake Ontario basin. However, the Atlantic salmon population declined sharply and was extinct by 1900 because of many factors such as mill dam construction, deforestation, and over fishing (Verdoliva 1999). Ontario and New York State began to stock salmonids in Lake Ontario regarding the economic potential in the late 1960s, especially between 1968 and 1974 (Crissman 1976). These stockings were made to provide a put and take sport fishery. However, due to severe sea lamprey predation, survival and recovery of early planting were very low. To rectify this problem, sea lamprey control was started in the tributaries of Lake Ontario in 1971 on the Canadian side and in 1972 in New York tributaries. Salmonids usually return to the stream for their spawning migration. However, because of the low flow level of many tributaries to Lake Ontario during the fall caused by shoaling and dry weather and relatively high concentration of contamination, fewer suitable tributaries left. During the fishing season, several communities along the lake and the estuary provide additional facilities for easy access of anglers. As a project of increasing facilities, a harbor of refuge was developed at the Salmon River.

5.2.2. Erosion and Water Contamination

Movement of water to and from lakes by surrounding groundwater and rivers are important links to lake water chemistry. Soil and aquifer weathering processes are key determinants of the chemistry of lakes and their response to long term and short term change. External loading of lakes from groundwater is determined by the thickness of porous, sediments, integrated length of the groundwater flow paths, hydraulic conductivity of the aquifer, and specific minerals that constitute the permeable aquifer. For this reason, geological aspects of ground water, open water, and sediments are dealt with importance.

As noted by our Physiochemical group, changes in land use will accelerate soil erosion and overland flow. Accordingly, eutrophication of the Lake Ontario will also increase by the effect of nutrient loading from the Salmon River, estimated flow of 25.2 m^3/s.

The reduction of persistant toxic substances from the Lake Ontario ecosystem is one objective of the Lake Ontario Toxics Management Plan (LOTMP) and the Lake Ontario Lakewide Management Plan (LaMP). Chemical pollutants enter Lake Ontario via atmosphere deposition, non-point source surface runoff, contaminated sediments, hazardous waste sites and current industrial/municipal discharges. The primary pollution problems are eutrophication and siltation caused by excessive nutrients from agricultural land and on-site disposal system (see Chapters 1 and 4). Although the amount of nutrients from the Salmon River that contributes to Lake Ontario is not apprehensive, the continuous increase of nitrogen and phosphorus from farmlands should be considered as a critical source of lake pollution. An identified discharger to the Salmon River is Schoeller Technical Papers Inc.[2] and two direct dischargers associated with Lake Ontario priority contaminants are Alcan Sheet & Plates (PCBs – 0.0001mg/L) and Oswego East Side STP (Lead – 0.085 lb/day) related to a contaminated wetland area adjacent to the facility (Luckey 1997).

The concentrations of many of these persistent toxic substances may be at or above current analytical detection limits. However the biomagnification of these chemicals through the food web can results in the accumulation of significant contaminant levels in higher organisms such as lake trout, salmon and bald eagles. In

[2] Effluent lead levels from Schoeller Technical Papers Inc. have been 0.003mg/L, well below the permit limit of 0.025 mg/L. Fluorescent lighting ballasts containing PCBs from Northeastern Steel, Rte.13, at Altmar, Oswego adjacent to a large swamp have been identified as contaminants of concern.

this regard, it is important to collect and synthesize the considerable amount of information that exists on potential and known sources of bioaccumlative contaminants within the NY LO drainage basin. The New York State Department of Health issues fish consumption advisories with recommended limits for particular fish species taken affected waters. In the Salmon River, smallmouth bass should not be consumed more than once per month because of PCB and Mirex. In addition, according to 1992 data of DEC, although the macrobenthic community showed no impact on water quality in the River, it was still rated as“fair” status due to existing fish advisories and the levels of inorganics measured in the water column.

5.2.3. Research Questions for Further Studies on Lake Ontario-Tributary Linkages

As a program of FL-LOWPA, the Oswego County Water Quality Coordinating Committee puts relatively high priority on developing a GIS-based watershed modeling and management plan for Salmon River restoration. The goals are to regulate water level and water quality; to restore fish habitat; to create a corridor along the stream (GIS group); and to manage flooding that has recently created unstable segments of the riverbanks.

In the perspective of interaction between lentic and lotic system, what research questions can be raised for further study? Human perception on lakes and rivers influence decisions by humans such as development, deforestation, and tourism. How does lake variation (seasonal and longer term) influence human decisions and attitudes toward the watershed system?

Lake effect climate change is well known for areas surrounding the Great Lakes. Then, how do these lake effects express themselves in a small watershed? The effects are closely related to the form of forests surrounding the Great Lakes as well as the riverine system.

In social perspectives, tensions between preservation and use of lands around the Great Lakes provide impetus for legislative and regulatory activity. Because of the characteristic of bi-national jurisdiction of the Lake Ontario, the Salmon River Watershed is also in the boundary of bi-national regulations or agreements. How do these attitudes and conflicts on the use of land adjacent to the lake influence the legislative and regulatory activities?

As regards integrating perspectives on river-lake ecosystems, are there more general models that may be used to describe lakes and rivers as part of a larger system or can we develop models that describe these in an integrated lake-river model system? How does one modify such river concepts for stretches of river feeding into lakes? These questions might interest businesses, governments, as well as researchers.

5.3. Ecology of the Salmon River Watershed: Structure and Function

The social and economic character of the Salmon River watershed depends upon the structure of the stream ecosystem. The structure of the watershed describes several components: the biological community, energy and material resources, and the gradient of environmental conditions within the watershed (Odum 1967). Historically, the ecological richness of the Salmon River has provided opportunities for economic development. Townships along the river corridor continue to rely upon the viability of the salmonid fisheries. This development has placed overwhelming stress on the structure of the ecosystem and limited its functional capacity. Function describes the rate of biological energy flow, the rate of nutrient cycling, and ecological regulation (Odum 1967). The past collapse of the salmon fishery and the current struggle to establish natural spawning stocks exemplifies the inability of the watershed to withstand the unmanaged human manipulation of biological communities. Therefore management strategies must consider the processes that contribute to productive fisheries. More specifically, once the structure of the system is identified, we can begin to trace the flow of energy through the food chain and identify the environmental factors that ultimately influence the status of secondary production. As seen in the case of the Salmon River, the degradation and/or contamination of the stream habitat can lead to conditions that discourage salmon from reaching optimum distribution and abundance.

Rather than construct a species-specific trophic analysis for the Salmon River, this discussion will focus on the role of several structural components in determining salmonid fitness. Fitness can be measured as an organism's ability to maximize reproductive potential through the selection for energy surpluses (Hall et al. 1986). This concept will be of particular interest when discussing the role of the hatchery produced fishes in the Salmon River. It is also important to note the influence that a complex migratory salmonid life cycle has on habitat requirements. From spawning and rearing in the headwaters to foraging behavior in Lake Ontario, salmonids have species-specific habitat regimes that are dynamic over time and space.

Given that riverine systems are typically net heterotrophic, the flow of organic matter from adjacent lands has a significant impact on ecosystem function. Riparian vegetation contributes leaf detritus and large organic debris directly into the stream. Through microbial decomposition and invertebrate consumption, this energy supply and nutrient base can transfer through trophic levels and is made available to salmonids (Murphy and Meehan 1991). In terms of physical habitat protection, tree root systems prevent stream bank erosion and protect salmonid spawning habitat. Riparian vegetation can dramatically influence the gradient of environmental conditions in a headwater stream. The canopy provides shading, controlling water temperatures, dissolved oxygen concentrations, and rates of primary production (Bjornn and Reisner 1991). Another indirect source of organic matter can be attributed to beavers and browser populations. Beavers transport woody debris while browsing mammals, such as deer, transfer material through defecation (Murphy and Meehan 1991). The processes that maintain the flow of energy through the food web are critical to the fitness of salmonid populations. It could be hypothesized that the fitness of natural reproducing salmon stocks would be reduced under circumstances where development patterns compromise these habitat requirements.

Predator-prey interactions and forage food abundance within the Salmon River watershed comprise a pelagic food web that deserves special attention. Biological regulators have the capacity to alter structure and energy flow. The success of salmonid reintroductions has been dependent upon the level sea lamprey (*Petromyzon marinus*) predation in Lake Ontario. The chemical control of sea lamprey populations began in the early 1970's and succeeded in reducing predator densities and increasing lake trout survival (Elrod et al. 1995). Sea lamprey biomass can be directly correlated to salmonid abundance (Heinrich et al. 1980). Therefore, stocking intensities should take into account the sea lamprey biomass assessments. Future sea lamprey management strategies must recognize they have the potential to influence salmonid productivity. In addition, overstocking of chinook salmon could stress alewife (*Alosa pseudoharengus*) populations and limit salmonid survival rates (Jackson 1996).

The state of New York has responded to the failure of salmonid stocks to reach self-sustaining levels by constructing the Salmon River Hatchery in Altmar. Since 1981, the Altmar hatchery has supplemented fluctuations in salmonid productivity and currently stocks chinook, coho, steelhead, and Atlantic salmon. The hatchery has created a year round fishery and is currently a fundamental resource for maintaining the sport fishing industry. As a reactive solution, hatcheries must continue to reevaluate stock size and abundance. Hatchery operation has the capacity to replenish salmon stocks but the fitness of salmonids will depend on the structure and function of the Salmon River and Lake Ontario ecosystems.

5.4. The Regulated Salmon River

There are currently three major barriers in the Salmon River: the dam forming the Lighthouse Hill Reservoir (downstream), Salmon River Falls, and the dam forming the Salmon River Reservoir (upstream) (Verdoliva 1999). The reservoirs in the Salmon River function as major storages of water that are used by Reliant Resources Inc. for hydropower generation, but also interrupt lotic patterns in the watershed. According to lotic paradigms such as the River Continuum Concept (Vannote et al. 1980) and the Serial Discontinuity Concept (Ward and Stanford 1983), biological communities tend to vary continuously along lotic systems in response to gradients of energy and nutrient inputs. Impoundments create a series of lotic and lentic areas (Ward and Stanford 1983), which in the Salmon River watershed influences a variety of functions ranging from biological habitats to anthropogenic uses.

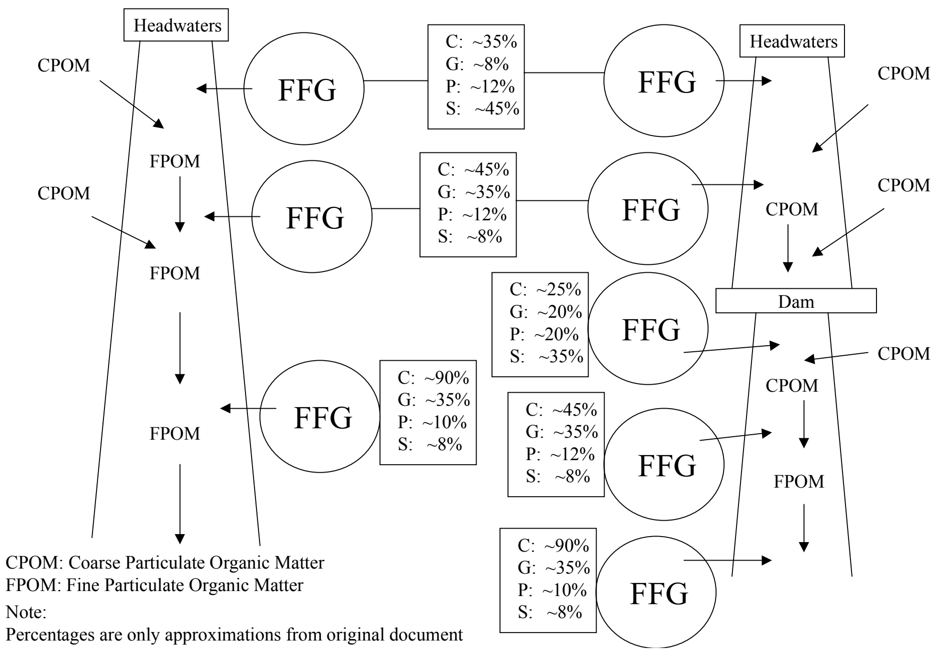
5.4.1. Salmon River Reservoirs

Reservoirs and lakes within a river system act as temporary interruptions to the flow of water in rivers (Gore 1996). Standing water bodies have very different physical, chemical, and biological attributes (Gore 1996). Between the two artificial reservoirs in the Salmon River watershed, the Salmon River Reservoir is much larger in size than the Lighthouse Hill Reservoir. This may indicate that the Salmon River Reservoir has longer residence times and slower rates of turnover (D. Bishop, NYSDEC, pers. comm.) Thus we can hypothesize that there will be greater rates of sedimentation, greater extent and likelihood of thermal stratification, and the increased presence of lacustrine life forms (phytoplankton and zooplankton) in the Salmon River Reservoir than in the Lighthouse Hill Reservoir.

5.4.2. Effects on Lotic Patterns and Production

According to the River Continuum Concept there is an expected trend in the life forms that inhabit any particular portion of a river and the degree of autotrophy vs. heterotrophy, as correlated to the hydrological and geomorphological trends along the river (Limburg et al. 2001). The Serial Discontinuity Concept expresses dams/reservoirs as resetting structures in the context of the River Continuum Concept (Limburg et al. 2001). Macroinvertebrates can serve as biological indicators of the types and amounts of organic resources that may be present in different areas of an aquatic system. Initial studies of benthic macroinvertebrates at upstream vs. downstream sites from the reservoirs in the Salmon River have indicated differences in the densities of functional feeding groups (J. Hallock, SUNY-ESF, pers. comm.). Natural and impounded rivers have different patterns of distribution of macroinvertebrate functional feeding groups (Gore 1996), as detailed in Fig. 5-3.

Fig. 5.3 MI Functional Feeding Groups C: Collectors, G: Grazers, P: Predators, S: Shredders
Adapted from: Gore, J. A. 1996. Responses of Aquatic Biota to Hydrological Change



It may be expected that further analysis of the macroinvertebrate populations in the Salmon River will show a relatively low number of collector and gatherer functional feeding groups just below the reservoirs as opposed to a continual increase in these groups as predicted for unregulated lotic systems.

5.4.3. Hydropower Generation

One of the major services of the Salmon River over the past two centuries has been the generation of hydropower from water stored behind dams. The two reservoirs in the Salmon River function as sources of potential energy that can be transferred into electrical energy by the hydropower facilities at Lighthouse Hill and Bennett's Bridge, which are run by Reliant Resources Inc. (RRI) (S. Murphy, pers. comm.). These two facilities have a nominal capacity of 42.5 MW or 6.5% of the total nominal capacity of all hydropower facilities run by RRI in upstate NY (http://www.orionpower.com/locations/assetdetails.cfm?AssetID=2). Currently, electrical energy generated by RRI is sold to Niagara Mohawk for a flat fee, who resells this power to residential customers (Murphy, pers. comm.).

5.4.4. Effects of Reservoirs and Hydropower Releases on Fish Habitats

Originally, the Salmon River hydropower facilities were run as peaking operations, with releases from the reservoirs ranging from 750-2000 cfs (21.2 – 56.6 m^3/s) to a leakage flow of 20 cfs (Bishop 1999). When there is not a constant release of water from the reservoir, the wetted perimeter of the channel directly downstream will continually change (Gore 1996). NYSDEC observations have indicated low levels of natural reproduction of chinook salmon prior to 1996 (Bishop 1999). Under the 1996 licensing agreement by the Federal Energy Regulatory Commission, minimum baseflows were established of 335 cfs (9.5 m^3/s) for September - December, 285 cfs (8.1 m^3/s) for January - April, and 185 cfs (5.2 m^3/s) for May - August (Bishop 1999). The minimum seasonal baseflows have resulted in increases in the populations of chinook salmon (Bishop 1999).

In large reservoirs, thermal stratification creates a coldwater hypolimnion from which hydropower facilities often draw water releases (Fowler, 1978). Thermal stratification is often accompanied by a chemical stratification, where lower strata may contain high levels of hydrogen sulfide (Fowler 1978). The variety of water quality changes, which may occur as a result of impoundment, may have negative effects upon fish populations that have specific thermal and chemical optima for survival and reproduction (Fowler 1978). In the Salmon River the Lighthouse Hill Reservoir is relatively small and has a relatively high rate of turnover (D. Bishop, pers. comm.). According to L.R. Wedge of the NYSDEC, the reservoirs are not deep enough to develop a coldwater hypolimnion (Wedge, pers. comm.). Research on water temperatures in the Salmon River have indicated that water temperatures beneath the Lighthouse Hill Reservoir are affected more by air temperature than by water releases from the Lighthouse Hill Reservoir (Bishop 1999). This would indicate that the Lighthouse Hill Reservoir is unlikely to have a significant impact on downstream fish populations in terms of thermal influences. It has been observed, however, that river water temperatures below the reservoirs have a tendency to remain warm later in the season due to the storing of heat in the reservoirs (L.R. Wedge, pers. comm.). These higher river temperatures have been noted to increase macroinvertebrate populations below the reservoirs (J. Hallock, pers. comm.), while preventing some fish populations, such as Steelhead Trout and Coho Salmon, from utilizing these areas as nurseries (L.R. Wedge, pers. comm.). It appears that potential effects of the Lighthouse Hill Reservoir on downstream fish populations may be influenced by multiple factors ranging from thermal influences of reservoir releases to changes in macro-invertebrate populations and total production levels predicted by the River Continuum Concept and the Serial Discontinuity Concept.

5.5. Other Anthropogenic Influences

Of the many factors that shape the watershed of the Salmon River, human induced influence has to be the most significant. It has shaped the area in many ways in the past and continues to do so now, especially in response to the changes that people have made that reduced the quality of the River’s natural resources.

Anthropogenic influences are, and have been, based on the natural benefits directly linked to the watershed its self. The Salmon River watershed is largely undeveloped with little land devoted to farming. The effects of fertilizer, herbicides, and pesticides that can have large impacts upon a watershed, are not as significant in this case. These are in fact located downstream, consisting of dairy and arable farming (VanderHeide 2002). The only industry, which is of size to mention, besides the hatchery, is the Schoeller Technical Paper Inc. Most of the watershed is forested with a variety of forest types. This is one of the most important factors for why this watershed has been able to come back as an internationally known location to angle for trophy-sized fish.

The community of the watershed has had to overcome a variety of human induced adversities, such as over fishing, and biological hazards to the fishing industry like the sea lamprey and zebra muscle. Though the sea lamprey problem has had some management success, the zebra muscle problem may have yet to reach its most damaging effects upon the fish community.

Some of the more recent developments to cause impacts have come from recent land sales by Niagara Mohawk of its 7,000+ acres. In this development, the "clear cutting" turned out to be more of a salvage cut (DeHollander, personal communication). In 1992, Niagara Mohawk began to sell off property with access to the Salmon River and/or reservoir from its property. An RV Park provides a way to attract vacationers, yet at the same time provide facilities that can accommodate their needs while reducing their impact on the countryside (O'Brien and Gere, Inc. 1998). Sales of the RV sites are likely to enhance the area's main economic boon, tourism. However, the Salmon River Greenway Corridor Community Enhancement Project, has been implemented to enhance the all around values that watershed has to offer (Oswego, 2001), and objects to further land sales within the Greenway Corridor. As of this writing, the fate of development in the Corridor remains unclear, although public consensus supports protection of the Corridor's integrity (L.R. Wedge, personal communication).

The fishing industry of the Salmon River has influenced the local economy since at least the 1950s, when there was a decline in fishing due to pollution and sea lamprey predation. The main focus of the fishing industry is on the 15-mile stretch, which makes up 2/3 of the River from the Lighthouse Dam to the River's delta at Lake Ontario, which is state land and open to the public.

The Salmon River fishery was stimulated in large part by the initiation of a Trout/Salmon program in 1968 (Bresadola, 2002). The program introduced coho salmon in 1968, chinook in 1969, steelhead and brown trout in 1973, along with lake trout after the sea lamprey was brought under control, and rainbow trout in 1974. Eventually, this led to the production of world-record-size fish coming out of the river through the 1970s and 80s. The Salmon River Fish Hatchery, which opened in 1981 and in 1997/98, had operating expenses of $169,000, played a crucial role in establishing the fishery. This has led to a tourism industry with an annual economy of more than $166 million, more than a 1,000 times the investment and the fish from the hatchery go to many other localities besides the Salmon River.

The watershed also has many other recreational attractions, which the local populus has been trying to capitalize upon. Attractions including the hunting of deer, turkey, grouse and others in the 40,000 acres of public land certainly help to enhance the year round economy of the area. Opportunities to camp, canoe, kayak, dive, bird-watch, and so forth create further tourism incentives. In all 5,900 people are employed in businesses that are 63% seasonally operated. A well-implemented idea the local people have used to promote the area is a "bed tax." This tax is a good way to make the business of tourism pay for its self.

It is not hard to see that the towns and townships of this watershed are all dependent upon the health and popularity of the Salmon River. The programs in place are necessary to the success of the fishing, but that the return far exceeds the investment, and depends on a healthy ecosystem.

The topographic and physical aspects of the watershed, combined with the chemical, biological and anthropogenic influences make for many complex influences and interactions. The watershed is driven both by natural and human forces. Through the years, the natural resources of the Salmon River Watershed have been exploited in many ways. Today the fishing and tourism industry is dependent on hatchery produced fish, but in the future, can the system sustain itself? That is an open question.

5.6. Conclusions

The Salmon River watershed is not the healthiest of ecosystems, but it has potential to regain some of its better natural qualities. Besides the many physical and chemical problems, some endogenous and others, like acid rain, exogenous, there is the difficulty of developing a consensus about how to deal with these issues. The River itself has changed so much over the years that it is not feasible to consider returning it to its "native" state either. So the question is, to what state do the communities want to see the River's watershed restored and maintained? What do we know about the watershed to make such important decisions? For as we have seen, there is a serious lack of knowledge of the system as a whole.

In terms of ecological integrity, the dams are a problem for the Salmon River. Maintaining dams for hydropower is a necessity that is unlikely to disappear. The recent flow regulation agreements are a major victory for the river's ecology, but even so, flows are far from natural. Plausible future development could include increases in logging, farming, or suburbanization. These kinds of changes could degrade the watershed, unless careful planning is implemented. Decisions made now and in the near future will have great impact on the future of the watershed and the future of the people who will inherit the land. Explicit recognition of the watershed's value, in terms of the ecological services it delivers to the local, regional, and state economies, may be a logical next step.