ALBANIAN WATERSHED ASSESSMENT

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The objective for the Albanian Watershed Assessment Project (AWAP) was to first identify the most critical watershed problems and then identify the factors or watershed characteristics that would allow identifying the most probable cause for those problems. An Assessment protocol was developed that identified those watershed characteristics most consequential to the problems and techniques for their measurement or quantification defined. The Assessment also addressed the socio-economic factors influencing both the cause of the problem as well as its mitigation.

The major sources of watershed degradation are: 1) erosion and sedimentation caused by poor land use practices, such as deforestation or gravel mining; 2) water quality problems resulting from industrial, agricultural, and municipal pollution; 3) air quality problems largely resulting from industrial pollution; and 4) flooding that is prevalent for a variety of reasons.

There appear to be 3 major problems in all of the major river systems: the frequency and magnitude of flooding is believed to be on the increase; sediment deposition, and the occurrence of saline soils, in the lower reaches of the river basin is increasing; water quality is degrading.

To best address the problems identified, the Watershed Assessment includes:

1. Evaluation of current and past trends in soil erosion and mass failure as sources of sediment introduced to the river system from: road construction and maintenance practices; land use practices such as timber harvest, cropping, or grazing; urbanization (special case of land use change); natural processes (surface erosion and mass failure).
2. Evaluation of the factors affecting sediment availability and transport in the river system. This issue addresses total transport from the watershed and, in concert with issues 1 above and 3 below, partitions the sediment load currently being transported by source (from bed and banks versus introduction from hill slope erosion or mass failure).
3. Evaluation of the current and past stream flow regime (primarily peak flow, total flow, and flow duration) as influenced by: reservoir construction; land use practices; gravel mining in the river; channel sediments (consequences of any change in stream equilibrium do to a change in either sediment load, the capacity of the river to carry the load, or both); natural variability.
4. Evaluation of the salinization process. Evaluation of trends in both erosion and sedimentation and the flow regime provide the technical base for understanding the causal relationships that lead to the occurrence of saline soils.

Two watersheds were selected for the assessment: Shkumbini, as the most appropriate Assessment watershed because of the diversity of activity, economic importance, and future development projections; and Vjosa, relatively undisturbed and as such represents a point of reference for Watershed Assessment. The framework that was used to identify, collect, and assemble the data for the assessment followed the protocol developed by McCammon et al (1998). For the watershed characterization, a Digital Elevation Model (DEM) was constructed based on 1:25,000 scale topographic maps, which was used as the spatial platform for positioning and subsequent analysis of all other spatial data. Hydro-meteorological data on stream flow and precipitation, and on soil and forest cover data were collected. The gauge site in square kilometers - drainage area and other additional characteristics that addressed soils, land use, vegetation, elevation, slope, aspect, etc. for each sub-basin were estimated using the GIS data base.

As with the hydrologic regime, it was critical to the Watershed Assessment process that the opportunity for erosion and mass failure be identified and that the distinction was made between areas that express a high risk (potential) for erosion but are currently stable, areas currently subject to erosion because of current changes in stability (land use), and areas which have been subject to erosion in the past but are once again stable. There is a significant interaction between high risk for erosion of the soil and on-going or proposed land use practices.

Related to flood plane characterization, the largest floods of record occurred in 1960,1970,1976,1980, 1996, and 1997. It was documented the extent of flooding on the coastal plane as well as changes in the coastline of the Adriatic, the degree of soil salinization, and the salinity of river water in the coastal plane area as a source of irrigation water.

Land use and cover type information was developed and displayed in a GIS format using a combination of historical aerial photography and recent Landsat 7 Imagery. Land use/cover type (e. g. a data layer describing the areas covered by forest, brush or shrub land, cultivated farm land, orchard, pasture, barren, sand/gravel, urban areas, streams, roads, etc) was characterized for each of 3 time periods from the late 1950's to the mid 1980's using aerial photographs. Landsat 7 Satellite imagery was used as a surrogate for aerial photography to estimate current land use/cover type condition. The US Forest Service, Remote Sensing Applications Group (RSAC) in Salt Lake City, Utah assisted us in the analysis of the satellite imagery. First, the images for the two time periods were georeferenced so that they could overlap and the watershed boundaries could be located on each set of the imagery without spatial distortion.

About 13 benchmark stations were established along the Shkumbini River and 15 stations along the Vjosa River for collecting data on channel morphology, sediment size, and channel classification based on the Rosgen (1994) technique. The data define periods of degradation (ca 1981) and aggradation (ca 1988) (scour and deposition) at the cross section while the long term trend indicates the river has down cut almost two-thirds of a meter during the 30 year period. A river, in equilibrium, tends to remain stable. Shifts in thalweg elevation of a meter in only 30 years are indicative of an unstable system.

A survey was conducted into current and historical gravel mining activity in the rivers of both watersheds (location and amounts of gravel extraction from the main stream and tributaries) for the period 1950 – 1999. Sediment data like particle size information from bed, bank, and bar locations in the river, at numerous locations, was determined in the field. Data, presented in grams.l^{-1} were paired with the discharge estimate at the time (day) the sample was obtained. The data allowed development of sediment transport models for various locations (stream gauge sites) within both watersheds. A significant observation is that the highest concentrations of sediment occur at the lower discharge levels. We assume the disturbance is the result of gravel mining.

Significant number of indicators or metrics were used to characterize the past, present, and reference condition of the Shkumbini and Vjosa Watersheds. In concert, the intent was to develop and organize the information or database necessary to characterize current and past watershed condition and to assess whether changes in condition, over time, could contribute to potential changes in erosion rates, sediment production, water quality degradation, and storm flow or annual runoff from the watersheds, and sub watersheds in a *cause and effect* format. In addition to the physical and biological characteristics, socio-economic data was collected for each watershed as part of a larger multi-national survey.

The Watershed Assessment analysis process had two distinct components. First, the data obtained to characterize current and past watershed condition was designed to provide the basis for evaluating the causal factors for increased flooding and sedimentation. The temporal and spatial analysis of factors affecting watershed condition addresses the issue as to whether or not any observed changes in activity within the watersheds could be held accountable for contributing to the perceived changes in the frequency and magnitude of flooding and sediment deposition. Second, an independent analysis of the stream flow and sediment data, documenting long-term trends in both discharge and sediment transport from the watersheds, addressed the question as to whether or not the frequency of flooding and elevated sediment deposition are actually occurring. Integrating long-term watershed response with long-term changes in land use practices on more than 30 sub-watersheds, allows partitioning of the most significant factors responsible for any documented change.

Much of the analysis was done using GIS techniques to spatially identify watershed characteristics and then compare trends in those characteristics over time with changes in stream flow.

The hydrologic change, which occurred between periods, was indexed as the difference in the hydrologic condition score for the two successive time periods that occurred as a result land use/cover type changes during the interval. To do this we assumed that a numeric relationship existed between hydrologic efficiency (numerical rating) and the land use/cover type classes.

All land use or cover types were rated some where between 1 and 10 depending on our perception of their hydrologic influence. The numerical ratings were very subjective but based on our understanding of hydrologic impacts of human disturbance on natural systems but the underlying assumption was that if a particular cover condition did not change over time, its impact on hydrology would not change. If there were a change in the cover class, the change in the score would be reflective of the relative change in hydrologic response with the range of high to low being 1 to 10. Changing the numerical ratings assigned to any given cover type would impact the average score for the watershed or sub-watershed but it would not likely affect the characterization of change or the outcome of the analysis. The numerical scores, between time intervals become “trends” which can be compared with what actually was observed to have occurred in the long-term measured stream flow. If for example, a unit of land that is cultivated today was in forest ten years ago, the consequence is that more stream flow should occur from that unit of land today than was generated from that same unit of land 10 years ago. If that unit were in brush today it would still produce more water than it would have as a forest 10 years ago, but less than if it were cultivated. We assume that the relative change in stream flow as a result of converting forest to cultivated land, or brush land, is adequately reflected in the change in numerical score between the land use/cover type categories. The analysis is done on a polygon-by-polygon basis.

In general, the changes in cover type and land use that have occurred over the past 40 years have had some impact on the hydrology of both watersheds. On average the impact would be slightly negative, implying that the potential effect has been to increase stream flow. However, the magnitude of change, on-site, does not seem great enough to demonstrate a measurable change in stream flow at the gauge downstream of the impact.

An erosion index, similar in concept to the hydrologic rating, was developed for each of the land use categories. To a large degree, the numerical score for the erosion ratings were simply the reverse of the hydrologic ratings. It is apparent from the analysis of the land use data that the opportunity for an increase in both stream flow and sediment does exist as a result of changes in land use from 1960 to present but the magnitude of that increase is not great. The degree to which the potential change can be detected in measured stream flow or sediment production measured in the stream channel was then determined.

Increased frequency of flooding was identified as a significant problem in every watershed proposed. A series of double-mass plots of both precipitation and stream flow were constructed following the techniques of Anderson (1955) to determine long term trends. In general, the precipitation data appeared to be consistent over time although a few gauges appeared to have some shifts in record stability. Finally, we looked at the relative amount of stream flow measured at one gauge with that measured at another gauge. A decline in stream flow at Rrogozhine, the lowest stream gauge in the Shkumbini River, is evident when compared to the stream flow at Paper, a few kilometers upstream. The interpretation, in this case, is that stream flow at Rrogozhine is declining and has since 1975 reflecting the impacts of the diversion of water for agricultural use.

The turbidity data was very consistent between gauging stations and watersheds. In virtually every instance, the highest turbidity values were associated with lower flows. In general, the highest turbidity values were not associated with either significant rainfall events or flow change. This would imply the elevated turbidity reflects a direct disturbance, most likely in the channel. We attribute the disturbance to gravel mining. The turbidity values themselves are extremely high, perhaps as much as one or even two orders of magnitude greater than what is commonly observed elsewhere. This elevated sediment transport both reflects and imposes profound changes in channel morphology, as evidenced by changes in channel cross-section and thalweg location.

The channel gradient and river cross sectional profile data gradient, elevation, width, and depth indicated that thalweg (River Centerline) elevations, at most stream gauging stations, have been quite dynamic over the past 40 years. Most cross sections in the main channels of both the Vjosa and the Shkumbini Rivers have demonstrated aggradation (deposition causing a rise in the river bottom) and degradation (down cutting) of as much as a meter in depth. It has been well documented that changes in river elevation at one point in the channel causes a migration of that change both up and down stream. In a simulation of river morphology near the Rrogozhine bridge, Molinas (2002) has shown that a 1-meter deep gravel excavation can cause changes in channel morphology in as much as 18 KM of channel in as little one year.

There does not appear to be a major change in the pattern in the last 15 years, other than there has been a lot of down cutting, causing sediment to move down stream, this in turn has aggraded the lower reaches and that rise in channel elevation, beginning at the Adriatic sea is now moving inland causing the channel elevations to rise in an inland direction. This drastically alters the river gradient, causing other river responses. One consequence is that the mouth of the Shkumbini River has moved northward 4.5 KM in the 14-year period from 1986 to 2000 cutting off several kilometers of river. In addition, the Shkumbini River is developing a delta, or depositing sediment at the confluence with the Adriatic Sea, that was not present prior to 1986. In order to dissipate energy, the river also makes other changes. Because the elevational gradient from Rrogozhine to the sea is so low (11 meters), the River cannot down cut again as a means of compensating and adjusting the gradient so it moves laterally, increasing bank erosion and migration. This can be seen in the changes if river location as evidenced on satellite imagery in 1986 and 2000. The net effect is that in the lower reaches of the Shkumbini Watershed the River is unstable, the River bottom is elevated, and although discharge has not increased, flooding is more prevalent and effective.

Summary and Conclusions. It appears that the frequency of flooding and the negative impacts of sediment deposition are on the increase, at least in the Shkumbini and Vjosa Rivers. However, the data available do not support the argument that discharges are increasing. If anything, discharge is decreasing because a greater amount is being diverted for off river use or storage. Sediment transport data does not indicate that turbidity levels are increasing. There is very significant sediment movement in the River, but the rate has not changed drastically over time. The largest spikes in sediment transport, as indexed by turbidity appear, appear to be more disturbance driven than either storm or discharge driven.

Evaluation of the effect of land use practices, and change in those practices, was very insightful. There is a lot of change occurring in how the land is used, but the net effect on stream discharge and sediment production, is not that great. The analysis, and spatial data base, is quite useful in documenting where the greatest change is occurring, the nature of the change, and where the greatest priority for remediation exists, either for physical, biological, or socio-economic reasons. The analysis indicates the most significant factor contributing to flooding and sediment is River instability caused by gravel mining. Until the stability of the River is addressed, attempts to drain flooded areas or remove or control sediment will fail. Information associated with land ownership patterns, population demographics, income sources, etc. was not directly used in the assessment but will be of most value in arriving at recommendations for intervention. Mitigation of the social and economic consequences of proposed intervention practices may be more significant an action than the intervention practice proposed. These issues will be addressed in the management plans, developed from the outcome of the Assessments.

On going activities conducted by AWAP include: digitize 1:25 000 scale topographic maps for the entire Albania; monitor and document the impact of gravel mining activity in three segments of the Shkumbini River and one segment of the Erzeni River; evaluation of changes in the channels of Vjosa and Shkumbini rivers; sediment transport from small steep-gradient watersheds in the Shkumbini; establishment of the new permanent forest sample plots; establishment of meteorological station, construction of anti-erosive fences and gabions, monitoring the effectiveness of restoration measures for erosion control, monitoring of soil erosion and vegetation in the experimental area of Qafe Shul, Librazhd; GIS mapping of all Albanian stream gauges (hydrometric) and rain gauges (pluviometric stations); planning of measures for rehabilitation of the affected areas in the Shkumbinbi River, the segment from Ura Rrogozhines to the Rivermouth.

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