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INTERIOR COLUMBIA BASIN WATERSHED DELINEATION GUIDELINES

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INTERIOR COLUMBIA BASIN
ECOSYSTEM MANAGEMENT PROJECT

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ABSTRACT

This document summarizes the logic, convention, and process steps used for the delineation of watersheds within the Interior Columbia Basin The document also includes sections on problems encountered, sources and descriptions of materials, and an example of a system to maintain, revise, and distribute the spatial data. The context for this work is established with a brief discussion of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) and its relationship with hydrologic units of various scales.

(KEY TERMS: watershed delineation, water resources geography, Columbia River Basin)

INTRODUCTION

In July, 1993, as part of his plan for ecosystem management in the Pacific Northwest, President Clinton directed the Forest Service to "develop a scientifically sound and ecosystem-based strategy for management of Eastside forests." The president further stated that the strategy should be based on the "Eastside Forest Ecosystem Health Assessment" (Everett and others 1994), recently completed by agency scientists, as well as other studies. To implement this direction, the Chief of the Forest Service and the Director of the Bureau of Land Management jointly directed that an ecosystem management framework and assessment be developed for lands administered by the Forest Service and Bureau of Land Management east of the Cascade crest in Washington and Oregon and other lands within the Basin (Eastside Ecosystem Management Strategy Charter, Thomas and Baca l/21/94).

The Forest Service (FS) and Bureau of Land Management (BLM), with the FS as lead, are charged with developing an ecosystem approach to guide assessment, planning, and management of forest, rangeland, and aquatic systems on federally-administered lands within the Basin (Figure 1). The scope of this charge emphasizes the need to integrate terrestrial and aquatic systems to address many of the issues related to the biophysical and social ecosystem components within the

Basin. For this reason hydrologic units were identified as the basic characterization and sampling units to be used for the assessment. This, in turn, identified the need for hydrologic unit delineations that would be 1) continuous across the Basin, 2) consistent in logic, convention, and process, and 3) of sufficient quality and resolution to meet the needs of the assessment and be of immediate use to land managers across the delineation area.

Watershed delineation has occurred at various places throughout the Basin for a variety of purposes. These efforts were inconsistent in logic and conventions and did not result in a consistent and continuous delineation product suitable for use in this assessment or other large scale efforts that cross jurisdictional and property boundaries. Given the absence of an existing delineation product, the Landscape Ecology staff group of the Science Integration Team ICBEMP developed logic, convention, and process steps in cooperation with other ongoing interagency efforts. The initial draft of this document (Brewer and others 1994) included extensive input from Bruce McCammon, Pacific Northwest Regional Hydrologist, thereby incorporating the guidelines used by the Oregon interagency team as well as information on the process used in Washington. Also included in this initial draft were the general guidelines (Anderson 1994) adopted by the Watershed Mapping Committee of the Idaho Geographic Information Advisory Committee (IGIAC). Coordination with IGIAC also provided the project a link to the national Watershed Delineation Team Leader (Ervin R Cowley, BLM representative to IGIAC) for information regarding the national standard guideline proposal. Subsequent meetings with Montana Interagency Steering Committee, and the Utah Interagency Watershed Group indicated substantial agreement in direction and/or guidelines.

The ICBEMP guidelines, as well as the other guidelines mentioned, based the numeric coding system on the one prepared by the U. S. Geological Survey (USGS) in cooperation with the Water Resources Council (WRC). The system consists of fields of paired digits referred to as Hydrologic Unit Code (HUC). The first four fields (8 digits) are assigned and published by the USGS (referred to as 4th field HUCs). The ICBEMP guidelines, as well as most of the others referenced, further subdivide the 4th field HUCs into smaller nested 5th field and 6th field hydrologic units.

Most of the interagency efforts discussed above follow guidelines very similar to the Natural Resource Conservation Service's (NRCS) "Guidelines for Mapping and Digitizing Hydrologic Units". New Mexico has adopted the NRCS guidelines completely and Idaho has incorporated most of the guidelines as modified by Cowley (1995). The NRCS guidelines are similar to those contained in "A Hierarchical Framework of Aquatic Ecological Units in North America" developed by the Forest Service and somewhat similar to the Alaska Aquatic Information Management System developed by the BLM in Alaska. The guidelines used for this project and described in this paper are consistent with the NRCS guidelines with proposed modifications (Cowley 1995). Departures from these guidelines are specifically noted within the appropriate sections of this document. Similarly, the definitions of terms are consistent with those in the NRCS guidelines unless otherwise noted. (Note: the term watershed, catchment, and hydrologic unit are used interchangeably and the NRCS definition of hydrologic unit would apply to all of them. “An area of land above or upstream from a specific point on a stream, which is enclosed by a topographic divide such that direct surface run-off from precipitation normally drains by gravity into a stream or the area above the specific point on a stream.“)

As discussed above the scope of this assessment emphasizes the need to integrate terrestrial and aquatic ecosystems using watersheds as the basic characterization and sampling units for the project. Details of how watersheds are used in the assessment can be found in the following assessment/analysis plans: Midscale Vegetation Characterization and Analysis Plan (Smith and Hessburg 1995), Framework for Aquatic Assessment (Lee and Rieman 1994), Aquatic Habitat Analysis Plan (McKinney and Over-ton 1994), Analysis Plan for Landscape Ecology and Hydrologic Function Group (Jensen and Goodman 1994), Vegetation Pattern Analysis Plan (Lehmkuhl and others 1995), Riparian Vegetation Characterization and Assessment Plan (Lee and Brewer 1995).

To meet the needs of these terrestrial and aquatic assessments the standardized delineation guidelines needed to address several project-specific objectives. These objectives, described below, were either not included in the NRCS guidelines or the guidelines were inconsistent with project needs. We, therefore, developed the methods described below each objective to meet the needs of the project.

Objective: Each hydrologic unit is to be assigned a unique numerical identifier, independent of State or other boundaries (using USGS/WRC codes as the basis).

Method: The NRCS guidelines address this issue within a State and provides unique numbers within a State. Our guidelines address the issue between states by delineating and numbering continuously across State lines, thereby, assigning a unique number to each unit. Our guidelines also departed from the NRCS numbering convention of beginning upstream and numbering sequentially downstream. Our guidelines assign numbers sequentially clockwise facing upstream, beginning at the “pour point” (defined as “the specific point on a stream” from the hydrologic unit definition from NRCS guidelines above). The rationale for this departure was to be consistent with the numbering convention adopted by the IGIAC.

Objective: Each hydrologic unit is to be assigned a unique numerical identifier which is compatible with existing watershed automated data processing models and programs.

Method: The NRCS guidelines assign 3 digit extensions for the 5th and 6th fields in the numerical identifier. Most FS and BLM programs and models are set up for 2 digit extensions for the 5th and 6th fields. Our guidelines assign 2 digit extensions to minimize conversion of models and programs.

Objective: Hydrologic units are the base characterization and sampling unit for aquatic and terrestrial assessments. Therefore, these units need to meet sampling design criteria.

Method: Sample units (delineated sixth field watersheds) need to be approximately the same area and meet other design criteria. A potential problem with using sample units of differing sizes, such as watersheds, is the well-known correlation of some landscape pattern attributes and map extent (area) (O'Neill and others 1988, Turner 1989). Studies of forest pattern in western Washington, however, have shown that sample estimates of landscape attributes change asymptotically rather than linearly. Lemkuhl and Raphael (1993) found most landscape pattern variables differed significantly when map extent increased from 2000 HA to 3250 HA around fixed locations, but few variables differed in value between 3250 HA and 7325 HA landscapes. Additionally, results from the Eastside Forest Ecosystem Health Assessment (Lemkuhl and others 1994) indicated that hydrologic units averaging 10,000 HA with a range of approximately 2,500 HA to 14,000 HA were ideal for characterizing and evaluating spatial patterns and significant trends in vegetation structure, composition, and susceptibility to disturbances. There is reason to expect the ideal range for characterization of non-forest areas should extend to 20,000 HA due to differences in the scale ofvegetation pattern and processes. This project used the range of 2,500 HA to 20,000 HA, varying with the geoclimatic setting and vegetation types, for the delineation of the 6th field hydrologic units. These units then became the base sampling unit for the stratified random sampling design described by Smith and Hessburg (1995) used in the mid-scale assessment. This range of values roughly corresponds to the range defined by the NRCS guidelines but does not provide for the exceptions to be mapped down to 1,200 HA.

TRIBUTARY DELINEATION CONVENTION

Due to the large area to be delineated in the CRB project personal knowledge of drainage networks throughout the region would be impossible to acquire. It is therefore very important for the delineator to become familiar with landscape patterns on a large scale. We found that United States series, 1:250,000, USGS topographic quadrangle maps (hereafter 1:250K quads) worked well for this purpose.

Working with Intermediate series, 1: 100,000, USGS topographic quadrangle maps (hereafter 1: 1 OOK quads) segments the landscape and, as a result, major pour points can easily be missed if they fall near the edge of a map. For this reason we approximately delineated any "true" fifth field watersheds on 1:250K maps first. This process gave us the perspective needed when approaching the delineation and subsequent attributing of watersheds on the 1: 1 OOK quads.

The steps in delineating a 1: 100K quad are as follows:

1) Start with the largest (highest order) stream and, moving along this stream, stop at each tributary and determine the aerial extent of its drainage basin. Delineate any true watershed- tributary (NRCS guidelines definition: Hydrologic units, with all flows converging at a single point "pour point" or low point along a stream.) with drainage area greater than the minimum in your range of area (in the ICBEMP delineation, 2500 HA)

(Figure 2). Keep in mind that large tributaries may not be completely delineated on a single quad map but they should be considered one hydrologic unit and their pour point should be delineated accordingly. This is where the 1:250K maps are a useful reference.

2) When you have finished with the largest river some of the delineated drainages will be in the size range of 2,500 to 14,000 HA. These will be sixth fields and will be aggregated with composites (see Steps 3 & 4) to form logical fifth fields. You may also have drainages between 12,000 HA and 20,000 HA. These are above the maximum sixth field size limit but below the minimum fifth field limit. They must, therefore, be delineated further and grouped with other sixth fields (either true or composite) to form a fifth field. Finally, there will be drainages between 20,000 HA and 60,000 HA. These will be fifth fields (they should correspond closely to those delineated on the 1:250K maps) and need to be further delineated with the same approach used for the mainstem in Step 1 (Figure 2). Eventually you should have all true watersheds greater than 4,000 HA delineated (Figure 3).

3) This leaves areas known as composite watersheds- between the true watersheds (NRCS guidelines definition: Hydrologic units that contain two or more streams that do not converge at a single point. Streams are usually a small size and intermittent or ephemeral. Composite watersheds include frontal and interfluvial areas.). These composites occur at all scales.. In other words, there are composite areas which are fourth fields, fifth fields, and sixth fields. These are simply areas which cannot be delineated as a true watershed. They often have a jagged shape along the entire length of a stream or river (Figure 4). These must be broken up into areas which are as logical as possible and which meet the upper and lower area limits.

4) To divide composites one should start with the most logical breaks (i.e. dams, pour points of major tributaries, a change in geomorphology, etc.). From the chosen break points, the delineation should run up the opposite ridge to the first delineated hydrologic boundary encountered (Figure 5).

ASSIGNING ATTRIBUTES

As with the actual delineation process, maintaining a landscape perspective helps greatly when assigning logical, sequential numerical identifiers to drainages. We adopted the convention used by IGIAC (Anderson 1994), numbering drainages in a clockwise manner.

Starting with the drainage containing the pour point we numbered sequentially, clockwise, “facing upstream”, around the entire catchment until the last drainage to be numbered was adjacent to or near the number 01 drainage. This method was used both for numbering fifth fields within a fourth field and for numbering sixth fields within a fifth field.

PROBLEMS ENCOUNTERED

Conceptually, watershed delineation seems like a straight forward process. Over a small area with distinct topography, and when good local knowledge is available, it may be. In delineating watersheds over the entire Columbia River Basin we encountered several operational difficulties.

On areas of little topographic relief several problems arise. These include diversions, braided channels, and minimal surface water. Our suggestions for dealing with these problems are as follows:

1) Diversions (i.e. canals and aqueducts) are common in agricultural regions of the ICB. The natural drainage pattern of many rivers and streams has been significantly altered. Inter-basin transfers of water are especially complex when attempting to delineate distinct basins. Extensive local knowledge can often help clarify things, but sometimes is not readily available. We dealt with diversions by delineating them as natural stream systems where they were functionally equivalent or, where there was no recognizable natural drainage pattern, we divided large diversion systems into groups. In many cases, this meant delineating across a canal in a place that made little hydrologic sense.

2) Braided channels tend to be very dynamic. An area of braided channels has most likely changed since the quad map was generated so the delineation is subject to error no matter what method is used. With this in mind, we chose one channel as the mainstem and delineated the tributaries as if they had pour points on that channel.

3) Dams and reservoirs were dealt with by delineating to the edge of full pool as shown on the quadrangle map. We recognized that when water levels are low a portion of the catchment is below the delineated pour point.

4) Large reservoirs and natural lakes pose another problem. These bodies of water along with any face drainages, which alone are less than 4,000 HA, can often be very large, exceeding the 60,000 HA maximum. Drawing a line across a large body of water as a watershed boundary, however, makes no sense so we chose to exceed the area limit in these cases.

As alluded to earlier, the most difficult obstacle in such a large delineation project is the physical handling of hundreds of quad maps. Delineating watersheds on mylar overlays, while maintaining map registration, is difficult enough to accomplish one quad at a time. The watersheds, however, occur on more than one map, and the maps must be arranged on a light table and exactly edge-matched to properly delineate drainages. This problem required a great deal of time and care to overcome and resulted in several rounds of spatial edits.

One final point which should be mentioned concerns the numbering convention. As described above we used the “clockwise method” (IGIAC convention). We did not adopt this convention, however, until after we had nearly completed the numbering using a "downstream method" (NRCS guidelines convention; i.e. the furthest drainage upstream is number one and the numbers increase as you go downstream with the pour point drainage having the highest number.

Having used both methods, we feel neither of these methods holds a distinct advantage over the other and either of the methods can assign a unique numerical identifier. The clockwise method works well on ideally shaped watersheds; the highest numbered drainage is adjacent to drainage number 01. Unfortunately, few watersheds have this shape and in reality the numbering rarely follows a true clockwise path. The same can be said of the downstream method. On some watersheds (e.g. long and narrow) this method seems to be more systematic than the clockwise method. On more heart-shaped or circular drainages, though, there is not much logic to the method.

SOURCE AND DESCRIPTION OF MATERIALS

There were two types of maps used in this project: base topographic quadrangle maps and mylar overlays. All base maps were 1: 1 OOK USGS topographic quadrangle maps. Most of the base maps were "USGS Editions", a few were "BLM Editions" with ownership as well as topography.

These base maps are available from USGS Earth Science Information Centers located in Spokane, Washington (for Wa, Or, Id, and Mt maps) and Menlo Park, California (for Ca, Wy, Ut, and Nv maps) or from the USGS Map Distribution Center in Denver.

Each quad map had two accompanying mylar overlays both of which had the quad name and quad comer tics plotted on them for easy vertical registration and identification. The first overlay was 1: 1 OOK resolution hydrography with streams and lakes shown in blue and the published USGS/WRC fourth field Hydrologic Unit Code (HUC) lines in red. The second overlay was left blank to draft the watershed delineations and identification attributes. The watershed delineations were manuscripted in a uniform line and black ink for the scanning process of electronic data capture. The identification attributes were manuscripted in photo-transparent blue or yellow to eliminate "editing out" the labels from the digital data layer.

DATA MANAGEMENT EXAMPLE

As discussed above, we collaborated closely with the IGIAC Watershed Mapping Committee throughout the process. As a result, IGIAC has adopted the ICBEMP delineation for release as a draft "universal, indexed watershed map and GIS product for Idaho" (Anderson 1994). This draft will be released to all cooperators and interested parties May 1, 1995 for IGIAC by the Idaho Department of Water Resources (hereafter IDWR), the designated lead agency. IDWR, through the IGIAC Watershed Mapping Committee, will accept comments and suggested revisions through May 1, 1996. At that time, the digital data will be revised and released as version 1.1 to be updated and re-released annually. This data layer will consist of continuous 1: 1 OOK resolution data from the ICB delineation effort. Subsequent refinements of this data at 1:24K resolution will be maintained as a separate discontinuous (until completed) data layer maintained and released through the same process. The ICBEMP should initiate a similar system, involving one or more cooperating agencies, to revise and re-release the spatial data for the rest of the Basin.

ACKNOWLEDGEMENTS

The delineation of watersheds across the entire Columbia Basin turned out to be much more complex task than any of us expected and without the gracious help and cooperation of many individuals and agencies we could not have completed it. The authors would like to acknowledge several key individuals for their special contributions to this effort. Bruce McCammon for his early support and advice as well as coordination with the Pacific Northwest Region, Michael Collette for his coordination with IGIAC and Intermountain Region, and Ann Puffer for her coordination with the Northern Region. Hal Anderson and Ervin Cowley were valuable contacts for advice and coordination with IGIAC and the National Watershed Delineation Team. And finally, Andy Wilson and Paul Newman for their excellent GIS support and digital data management expertise.

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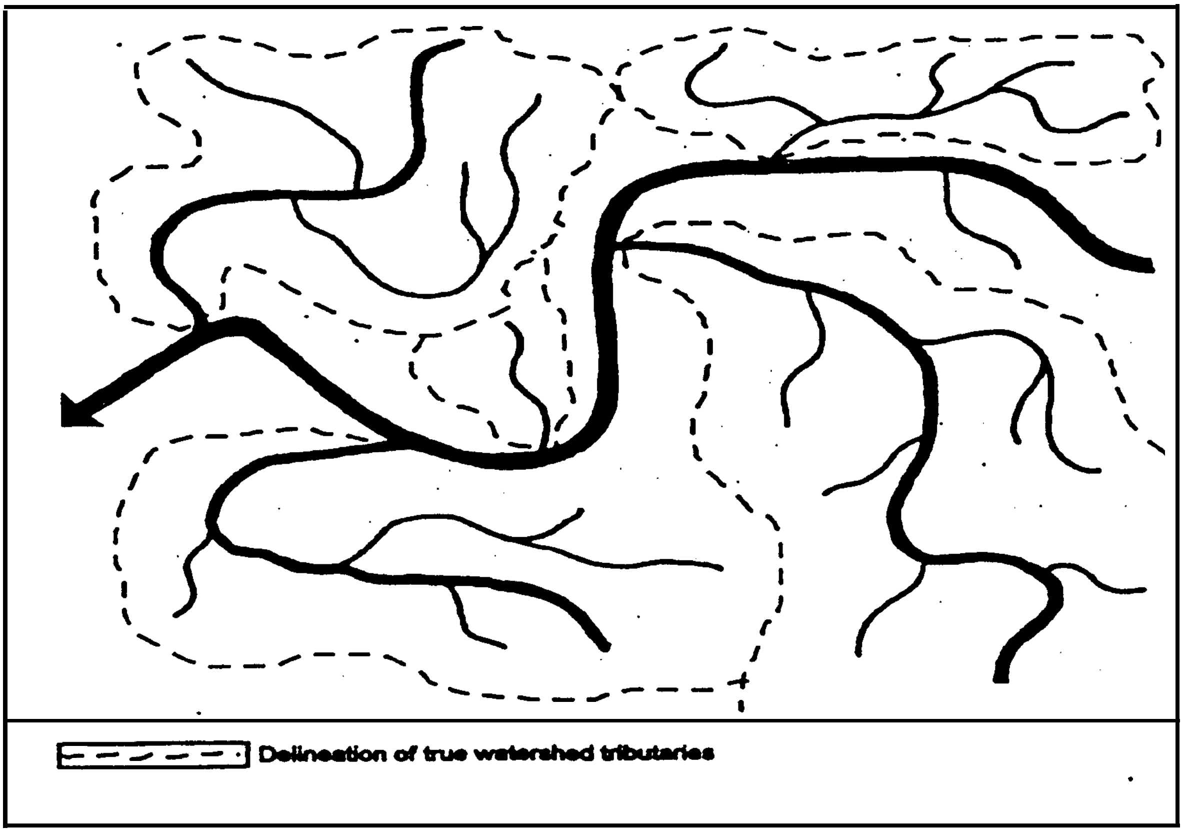

Fig. 2 - **First Pass Delineation** of TM **Watershed Tributaries**

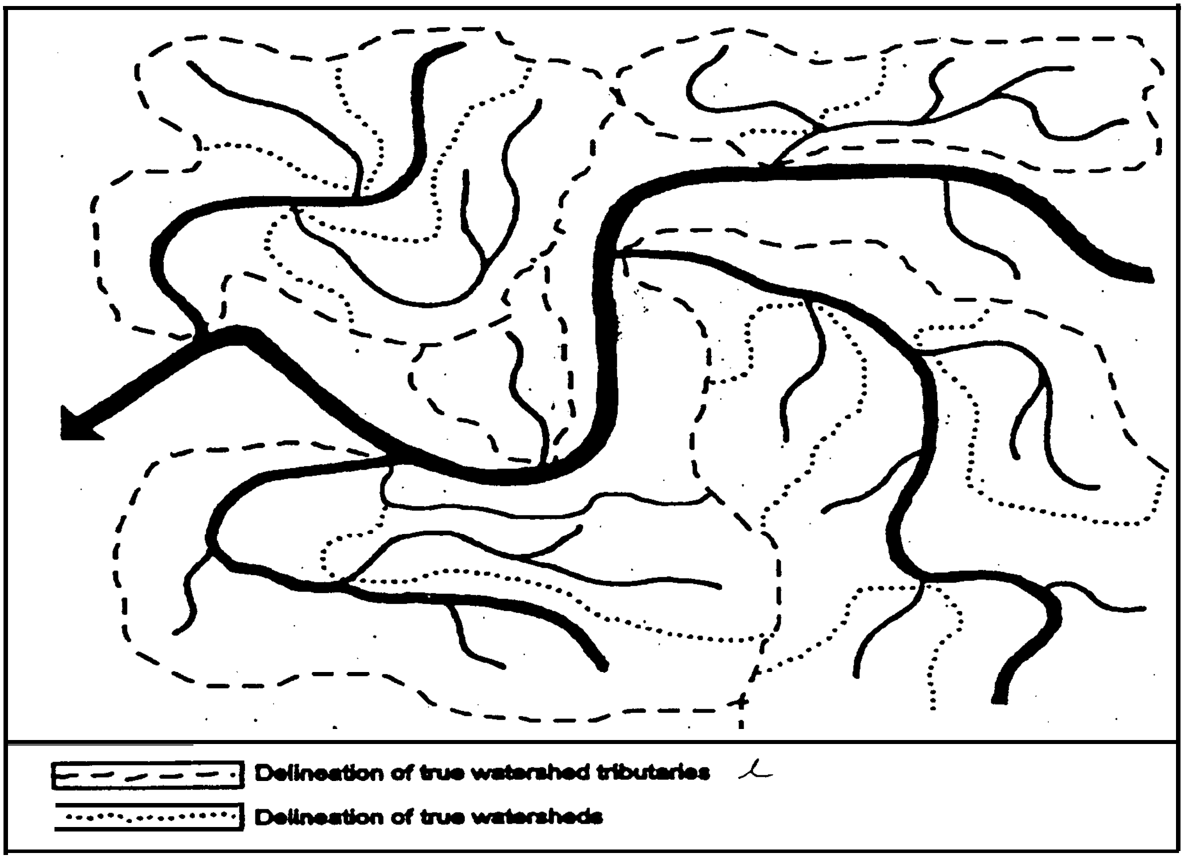

Fig. 3 - Second **Pass Delineation** of **True Watersheds**

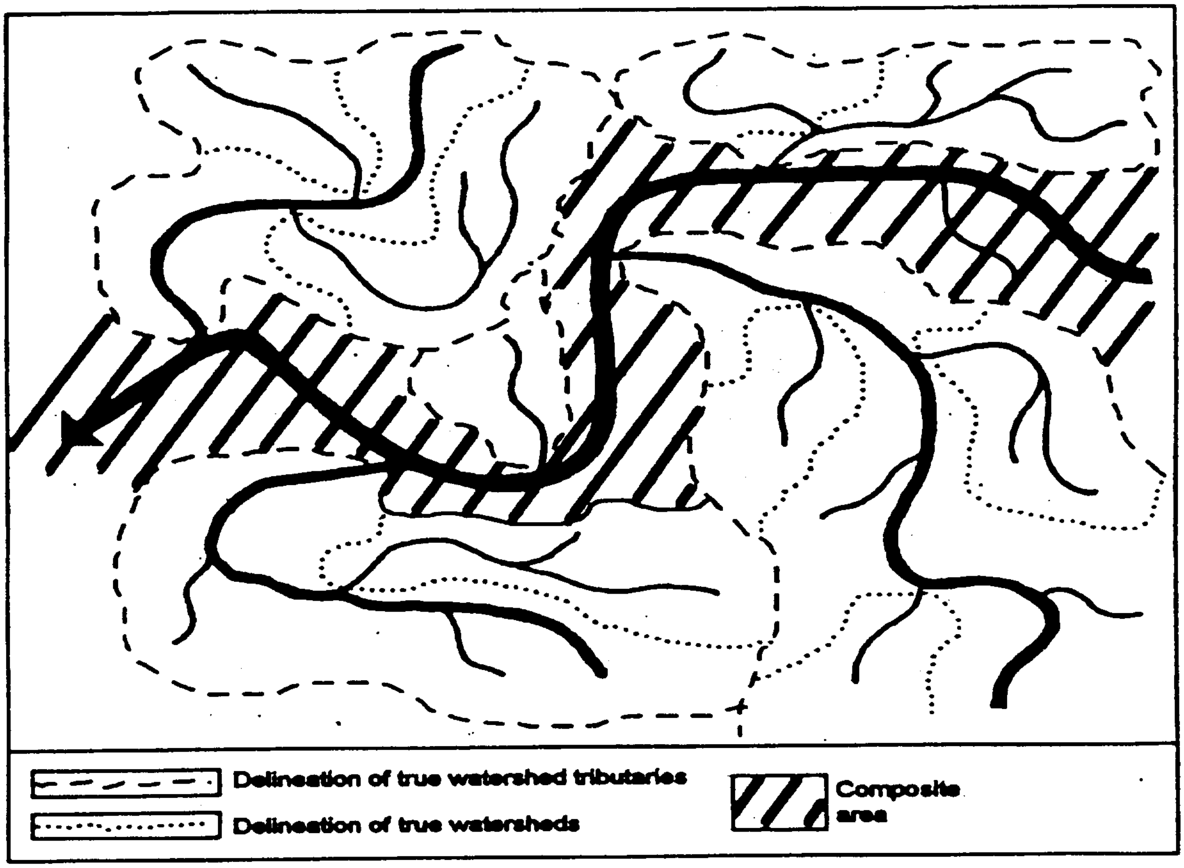

Fig. 4 - Composite Area

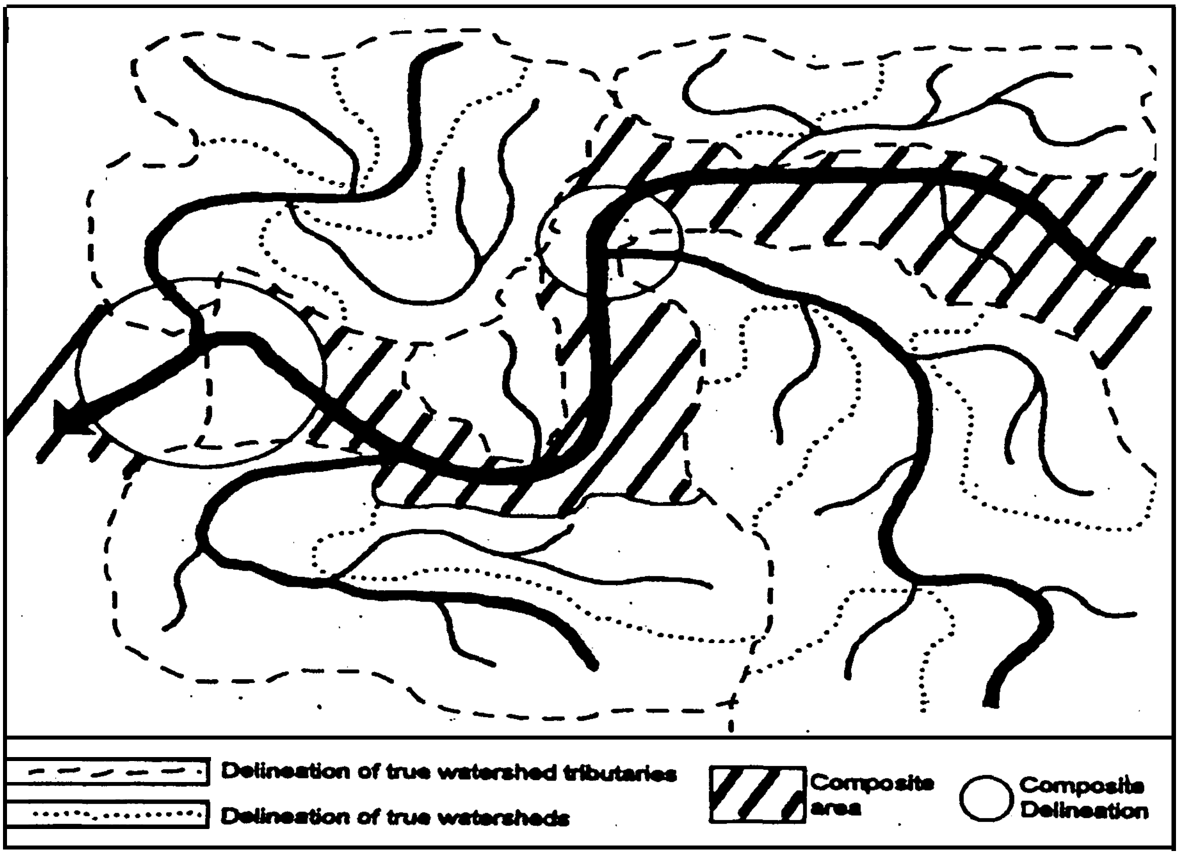

Fig. **5 - Composite Delineation**