Bedrock and Alluvial Controls on River Character and Behavior in Partly Confined Valley, Setting: Harsin Catchment, West Iran

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ABSTRACT

A partly confined river is one along which the contemporary channel abuts the valley margin along 10–90% of its length. They occur along sections of longitudinal profiles that are transitional from fully bedrock confined to fully alluvial rivers. At this position in the landscape, there is sufficient accommodation space for discontinuous floodplain pockets to form. Segregation of the river's load and dissipation of flow energy result in sediments being stored outside the channel. Bedrock- and planform-controlled variants of these rivers and associated floodplains are differentiated. Terraces act as secondary confining features on channel planform and floodplain formation in these valleys. The influence of these antecedent features on contemporary river character and behavior in partly confined valleys of the Harsin catchment, in Kermanshah, in Iran is appraised. The balance of formative and reworking processes, and associated capacity for geomorphic adjustment, is influenced by the site-specific configuration of antecedent controls at any floodplain pocket. KEY WORDS: Partly confined valley, Floodplain, Antecedent control, Bedrock-controlled river, Planform-controlled river, Alluvial –controlled river

INTRODUCTION

Alluvial and bedrock river channels are usually considered to be fundamentally different, with alluvial channels being shaped principally by flow and sediment transport processes, and bedrock channels principally by lithological and structural controls [1]. The formation of discontinuous floodplain pockets demarcates a transition zone along longitudinal profiles between confined and alluvial river variants [2]. Floodplain formation commences when sufficient accommodation space is available for overbank sedimentation to occur along valley margins. Segregation in the transport of the river's load creates sediment stores outside the channel on the floodplain. At these locations, the combination of slope and discharge (i.e., stream power) conditions is such that deposition and storage along valley margins mark a transition from dominantly erosion processes to the initiation of depositional processes [2]. Peaks in gross stream power generate significant potential for floodplain reworking in these relatively steep, mid-catchment locations [3, 4, 5, 6, 7]. Despite being key transitional elements of the fluvial landscape, limited attention has been given to the diversity of river forms found in partly confined or semi-controlled valley settings, and controls on their formation [8, 9, 10].

A partly confined river is defined as one along which the contemporary channel abuts the valley margin (or other form of confining feature) along 10–90% of its length [9]. Brierley and Fryirs [11] characterized two broad types of river within partly confined valley settings; bedrock-controlled and planform-controlled (Figure 1). Bedrock-controlled partly confined rivers are those in which the channel abuts a valley margin along 50–90% of its length. The channel is closely aligned with the valley, resulting in rivers with a low sinuosity planform. In sinuous valleys, alternating pockets of arcuate-shaped floodplain form on the insides of valley meanders, forming an alternating sequence of floodplain pockets along the valley floor. Channel and floodplain morphology is controlled by the configuration of the bedrock valley. In planform controlled, partly confined rivers the channel is able to adjust its position on the valley floor, but it continues to abut the valley margin along 10–50% of its length. Along these rivers the shape of floodplain pockets is determined by the planform of the channel, rather than the configuration of the bedrock valley. The range of planform-controlled river types reflects channel planform [9]. Partly confined river types have variable capacity to adjust in lateral, vertical, and wholesale dimensions [10]. This is controlled, in part, by the accommodation space in the valley (or within confining features). Bedrock-controlled variants have less capacity to adjust than their planform-controlled counterparts. Flow alignment relative to valley configuration controls the distribution of floodplain pockets. The location of bedrock outcrops and other confining features influence how

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The degree of geological or climatically controlled rivers are related to this section of the catchment. The highest parts of the catchment are mainly formed from conglomerate deposits in final Miocene, 200 to 300 meters thickness, and radiolarit in the final Jurassic to final cretaccus, and about 12.57 square kilometers catchment vastness belong to this geological section of the catchment.

By definition, the capacity for adjustment of rivers in partly confined valley settings is a direct result of antecedent controls set by past conditions. This imprint, or “geomorphic memory”, continues to influence contemporary river character and behavior [15, 16]. Various layers of antecedence can impact on contemporary process-form associations. At the broadest scale, geological controls including lithology, tectonic history, and rates of landscape dissection and denudation dictate the shape and confinement of a valley [17, 18, 19, 20]. Inset within this, climate controls rates of sediment and discharge supply, and vegetation cover, resulting in rivers with differing morphologies. If paleo-deposits are preserved within a valley, and are unable to be reworked, inherited morphologies will control subsequent process-form associations in that valley. For example, floodplain, terrace and fan materials that were deposited under former flow and sediment regimes can continue to influence the type and lateral stability of contemporary channels (16, 21, 22, 23, 24, 25). The degree of geological or climatically induced antecedent controls affects the capacity for adjustment of a river, and its sensitivity to human disturbance [24, 26].

Recent research in Harsin catchment in kermanshah, iran, indicates that over 97.7% of river flow within confined or partly confined valley setting, this article provides an account of the diversity and downstream patterns of river in partly confined valley setting, and the types of antecedent control that influence contemporary floodplain formation and reworking in this setting.

MATERIALS AND METHODS

Regional setting: Harsin catchment is located in southeast of Kermanshah in the west of Iran. It is geologically considered as a part of thrust zagros. This catchment is topographically divided into three categories: mountain, pediment, and plain. Its northern and southwestern mountain are mainly formed from the lime Achaean Era. The highest parts of the catchment are related to this section, and its age is known to be mainly from Triassic to cretaccus. Mountains such as shires, 2705 meters high, and derazkouh 1830 meters high are located in this section. This section of the catchment is 93.71 square kilometers. The south and southwest of the catchment is formed from radiolarit in the final Jurassic to final cretaccus, and about 12.57 square kilometers in the catchment. The Shams Abad Mountains whose highest part is 1775 meters high are mainly made up of this material. Scattered hills in the center and southeast of the catchment formed from ophiolite which is known as Harsinophiolite are probably created in Triassic [27]. The eastern mountains in the catchment, known as Gavan ban, with the height of 2500 meters, formed from lime in the Miocene, 200 to 300 meters thickness, and 33.25 square kilometers catchment vastness belong to this geological period. The south of the catchment is mainly formed from conglomerate deposits in final Miocene and bakhtiari (Paleocene) and is 25 square kilometers altogether. The most important mountain in this section is zarrin which is 2049 meters high. The pediment and plain in the catchment are mainly made up of Quaternary alluvial deposits which are the result of upper part erosion and being carried to lower part areas (Figure 2).The deposit unit in the Harsin catchment is located in pediments, terrasses, alluvial, fans and floodplain. The deposit unit in the Harsin catchment is 43.36 square kilometers. The average annual rainfall in this catchment is 383mm. and the maximum flood occurred in 1987/3/4 was 29.25 cubic meters.

Classification of river types and measurement of effective valley width: Air photograph interpretation was tied to field investigations and ground truthing to map the distribution of partly confined floodplains and confining features in the catchment. Aerial photographs (1:55,000) from 2002, 2003 were orthorectified using ERDAS Imagine 8.4. Floodplain types and secondary controls were identified using a stereoscope and manually digitized onto the aerial photographs. This procedure was completed along all major stream networks in the harsin catchment to a point where the size of the floodplain pocket was beyond the resolution of the aerial photos. Mapping and categorization of all floodplain pockets were checked in the field. Three types of rivers with discontinuous floodplains were identified in partly confined valleys in the harsin catchment, namely; (1) bedrock-controlled rivers, (2) low sinuosity planform-controlled rivers, (3) meandering planform-controlled rivers.

Secondary features that add an additional layer of confinement in these valleys were also classified two forms of secondary control were identified, reflecting the nature of the confining media; fan control, terrace control. Because of the presence of these secondary confining features in many valleys, measures of total valley width become virtually meaningless. Hence, a measure of “effective valley width” has been used to reflect the degree to which the secondary confining features

Figure 2. Location of the Harsin catchment and landscape.
limit the capacity of the channel to adjust its position on the valley floor under contemporary environmental, climatic and flow conditions. Hence, effective valley width is measured as the width of the valley floor within the confines of bedrock or other confining feature (i.e., fans, piedmonts, terraces). Existing GIS data sets were used to determine catchment area, floodplain size, effective valley width, local slope, and gross stream power for each floodplain pocket. Downstream patterns of floodplain pockets in partly confined valley settings were analysed along longitudinal profiles of 26/3 km of streamline in the Harsin catchment. The number of floodplain pockets of each type was counted along segments of river. Each segment was demarcated by major tributary confluences.

RESULTS

Floodplain morphology in partly confined valleys of the Harsin catchment: A total of 515 partly confined floodplain pockets were classified and assessed in the Harsin catchment. Terraces are the primary control on the formation of these floodplains, totaling 409 pockets (80%). The main form of secondary control was induced by Bedrock (92; 18%). Fans are confining features along 11 (2%) floodplain pockets, respectively. Figures 3–5 and Table 1. Highlight the geomorphic character and behavior of the three main partly confined river variants.

Bedrock-controlled discontinuous floodplains: Along the bedrock-controlled discontinuous floodplain river type, the channel abuts a bedrock (or in many cases, terrace) margin along 50–90% of its length (Figure 3). Valley sinuosity is generally N1.5 producing distinct valley morphology with alternating bedrock spurs. Arcuate-shaped floodplain pockets alternate along the valley floor on the insides of valley bends. These floodplain pockets have an average width of 63.86 m, an average length of 375.56 m, and average area of 136.24 m² (Table 1). The floodplains are typically characterized by a stepped morphology with various planar surfaces. In the Harsin catchment, 92 bedrock-controlled discontinuous floodplains were identified, representing 70% of the floodplains analyzed in this study. While the location of these floodplains is dominated by Terraces control (80%), bedrock also acts as a significant confining feature in these valleys (18%). Terraces that are perched above the floodplain surface tend to be preserved in sheltered locations behind bedrock spurs that define the sinuous valley margin. Floodplains are inset within these features. Fans subclasses of this river are less frequent (2%).

Low sinuosity planform-controlled discontinuous floodplains: Along the low sinuosity planform-controlled discontinuous floodplain river type, the channel abuts a bedrock (or in some cases, terrace or fan) margin along 10–50% of its length (Figure 4). The valley is relatively open and straight. Occasional bedrock spurs impinge into the valley. Between these spurs distinct alluvial fans may form, extending onto the valley floor. These bedrock spurs and fan deposits dictate the location and size of floodplain pockets. The low sinuosity character of the channel is controlled by the position of fans and Bedrock spurs that act to the channel to one valley side before abruptly shifting to the opposite valley side farther downstream. As a result, floodplain pockets alternate along the valley floor. The shape of the floodplain pockets varies significantly depending on the nature and location of the confining materials. Floodplain pockets have an average width of 88.29 m, and an average length of 457.52 m, giving an average area of 213.22 m² (Table 1). The floodplains themselves tend to be planar and relatively featureless, but may contain an occasional surficial high flow drainage line (termed a flood runner) where the Channel switches position from one valley side to another.
In the Harsin catchment, 244 low sinuosity planform controlled discontinuous floodplains were identified, representing 80% of the floodplains analyzed in this study. Around 79.91% of these are dominated by Terraces control. Fans and bedrock are the dominant forms of secondary confinement, affecting 17.62% and 2.45% of these floodplains, respectively. The floodplains either drape the fans or are inset against the terrace features.

Figure 4. Representative geomorphic map, field surveyed cross section and photograph of the partly confined valley with low sinuosity platform-controlled discontinuous floodplain River style. Air photograph reproduced from © 2011 Google Earth™.

Meandering planform-controlled discontinuous floodplains: The meandering planform-controlled discontinuous floodplain river type is similar in many characteristics to the low sinuosity variant, although the planform of the channel is sinuous (N1.59). The confining features include either buried or exposed fans and piedmonts, and buried or perched terraces. Along this meandering variant, the channel abuts a bedrock or terrace margin along 10–50% of its length (Figure 5).

Figure 5. Representative geomorphic map, field surveyed cross section and photograph of the partly confined valley with meandering platform-controlled discontinuous floodplain River style. Air photograph reproduced from © 2011 Google Earth™.

The valley tends to be relatively open and straight. Occasional bedrock spurs impinge into the valley. Between this confining media, extensive floodplain pockets can form. Because the channel abuts the valley margin along the concave bank of the bend, it has limited or no capacity to adjust laterally. Instead, the channel is able to translate downstream. Floodplain pockets tend to have an arcuate shape. Their average width and length are 119.99 m and 540.08 m respectively, with an
average area of 390/72 m$^2$ (Table 1). The floodplain surfaces tend to be planar, but may contain an occasional flood runner along the valley margin that short circuits the floodplain Pocket where the channel switches position from one valley side to another.

In the Harsin catchment, 215 meandering planform-controlled discontinuous floodplains were identified, representing 60% of the floodplains analyzed in this study. 78% of these are dominated by terraces control. Of those that contain secondary forms of confinement, bedrock is the dominant forms affecting 13% of these floodplains.

Table 1. Attributes of discontinuous floodplains formed along various types of partly confined River in the Harsin catchment

<table>
<thead>
<tr>
<th>Types of partly confined River</th>
<th>Average floodplain width (m)</th>
<th>Average floodplain length (m)</th>
<th>Average floodplain area (m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrock-controlled</td>
<td>63.86</td>
<td>375.56</td>
<td>136.24</td>
</tr>
<tr>
<td>Low sinuosity planform</td>
<td>88.29</td>
<td>457.52</td>
<td>213.22</td>
</tr>
<tr>
<td>Meandering planform</td>
<td>119.99</td>
<td>540.08</td>
<td>390.72</td>
</tr>
<tr>
<td>Average</td>
<td>90.71</td>
<td>457.72</td>
<td>246.70</td>
</tr>
</tbody>
</table>

Confluence-induced discontinuous floodplains: Confluence-induced floodplain pockets are relatively localized and vary significantly in their size and shape depending on the alignment and size of the confluence zone (Table 2). These floodplains are on average 90.71 m wide, 457.72m long and 246.72 m$^2$ in area (Table 1).

Table 1. The character and behavior of Rivers with discontinuous floodplains found in partly confined valleys

Pattern of partly confined rivers along longitudinal profiles in the Harsin catchment: The partly confined pattern by the valley along its longitudinal profile of the Harsin River has an abrupt break in the middle part. This part of the catchment is the place where the Harsin river meets the Babazeid Mountain and by cutting it has created the Babazeid Gorge. In the longitudinal profile, the Harsin River is located at 1568 meters and 1275 meters in the maximum and minimum height respectively. The river is 26.3 kilometers long. The Harsin river in the partly confined pattern by the valley includes 97.7% out of its total length in longitudinal profile. and only at the of the river i.e., from Shams bad village to the contact point with Gamasib river which includes 2.3% out of its total length is included in the unconfining pattern by the valley. In total longitudinal profile of this river, the most applied control over the Harsin river is done by terraces and it is 79.88%.bedrocks and alluvial fans come next with 17.96 % and 2.14% control over the Harsin river respectively. Except Babazeid Gorge where the main control is done by bedrock, the major control over the river is done by terraces in the rest of the river. Harsin catchment is geologically made up of three distinct geological materials. It is mainly formed from lime in the north, northwest, east, and south and in the central part. In this section of the catchment in the upper parts of the Harsin River, valleys have surrounded the Harsin river, or the river is flowing through the valleys in the planform way. Ophiolites are established in the forms of hills in the central and eastern parts of the catchment, and except Chagahseyyed village, they have the least control power in confining the Harsin river. Radiolarites include the west, southwest
and the outlet of the catchment, and the Harsin river is flowing in this part of the catchment in a planform way in the syncline of the Shams bad mountain which is mainly made up of this material.

**DISCUSSION**

**Partly confined rivers and the spectrum of river diversity:** The range of partly confined rivers documented in this article forms a subset of rivers that are controlled by bedrock valleys and secondary confining features of considerable antiquity. Antecedent controls on contemporary river character and behavior are particularly prevalent in this tectonically-passive landscape setting where preservation of palaeovalleys and palaeosediments is common [19]. When placed in context of the spectrum of river diversity found in partly confined settings, the examples highlighted here would be considered in terms of their capacity to adjust and the recurrence of floodplain formation and reworking. In more tectonically-active landscape settings, the morphology of partly confined floodplains may be similar, but formation and reworking processes are likely more recurrent [18, 28]. This highlights the transitional nature of these rivers in parts of landscapes where high energy and valley morphology set the potential for significant variability in floodplain forms and processes, a factor that is largely overlooked in the over simplistic differentiation of bedrock versus alluvial rivers.

**Antecedent controls on contemporary river forms and processes:** Partly confined river valleys and associated floodplains are a direct product of antecedent controls. These controls set the conditions within which contemporary floodplain formation and reworking processes operate. The antecedent imprint or ‘geomorphic memory’ varies from floodplain pocket to pocket, reflecting geological controls on valley width and alignment, and the persistence of secondary confining features [9]. The presence or absence of these features and their prevalence is valley specific, reflecting pocket-by-pocket variability in landform assemblages along partly confined rivers [29]. Antecedent controls can be differentiated into a number of “layers of imprint” that can be interpreted to gain a full picture of why certain types of floodplain form where they do [25]. These layers include geological control, within which are embedded climatic controls, and onto which a human imprint may be manifested. Geological controls refer to the structural and lithological characteristics of a catchment that dictate the ease with which rocks are weathered and eroded, the rate at which valleys develop, and the configuration of those valleys. Long-term landscape evolution, operating over millions of years, also impacts on valley formation and configuration [30]. Valleys with varying morphologies and varying amounts of accommodation space are produced [18, 20]. In Harsin catchment Gorges generally extend several kilometers downstream along the steepest section of longitudinal profiles where incision processes dominate. At the exit from these confined valleys (at the break in slope of the longitudinal profile) peaks in gross stream power occur and lateral expansion of valley sidewalls creates sufficient accommodation space for floodplains to begin to form [31]. Valley sidewall expansion forms a trough that permits channel adjustment and development of alternating floodplain pockets. In upstream sections of these partly confined valleys, or in areas with more resistant lithology, slow rates of sidewall expansion limit the extent of valley widening, such that the valley floor trough remains bedrock-controlled. Higher rates of sidewall retreat in downstream sections of these partly confined valleys have resulted in wider, more open valleys where planform-controlled variants of river can form.

Harsin River in the Harsin catchment drains more erodible Miocene and Paleocene sedimentary sequences. This produces longitudinal profiles that contain very short confined. Headwaters and long sections of partly confined and laterally unconfined valley. The partly confined valleys are relatively wide. The valleys are developed and are therefore dominated by planform-controlled, partly confined floodplains that contain extensive secondary confining features.

Climate controls the rate at which water and sediment are transferred through a catchment, the caliber of sediment that can be carried and the density of vegetation cover [9]. In addition, climate influences base level controls associated with sea level change [25]. These flux boundary conditions [11] interact with the landscape over thousands of years to produce various types of River. This mix of controls manifests itself in different ways, producing sedimentary sequences and landforms that infill valleys to various degrees and which reflect the nature of the flow and sediment regimes of a particular time in the past [23, 25]. As climate changes, transitions in River morphology occur. The morphology adopted is dependent, to some extent, upon the antecedent control exerted by previously deposited and preserved sediments that comprise the valley fill [25]. In the Harsin catchment, previous phases of sedimentation are recorded in preserved secondary confining features such as terraces, fans and piedmonts that formed, and have been preserved, over timeframes of tens of thousands of years. These landforms have added an additional layer of antecedent control that dictates the available accommodation space within which contemporary rivers could form. The shape, size and type of contemporary floodplain are direct functions of the type, position and extent of confining features in these valleys.

At different positions along the longitudinal profile, incremental vertical accretion of contemporary floodplains has been expressed in different ways. In the most upstream sections of partly confined valleys where valley accommodation space is limited, secondary confining features are either not formed or not preserved. These valleys are dominated by pockets of bedrock-controlled discontinuous floodplain. Further downstream in mid-valley locations, where more accommodation space is available, fans and terraces begin to occur. Initially these features occur in bedrock-controlled valleys, but as the valley morphology changes from sinuous to irregular, and as valley width increases, planform controlled variants of floodplain form. The extensive nature of the secondary confining features in many of these valleys limits the accommodation space within which contemporary floodplains may form. Given the relatively small catchment areas draining into these valleys, sediment supply from upstream is limited. As a result, narrow floodplains form adjacent to terraces or fans, leaving...
the terraces perched and the fans exposed at the valley margins. In their most downstream sections, partly confined valleys tend to be wider with more gently graded sidewalls, favoring the formation of planform-controlled floodplain pockets. In these settings, low-lying terraces are the dominant secondary confining features. In a similar way to upstream settings, these features restrict the accommodation space within which contemporary floodplains can form. However, these locations drain much larger catchment areas and sediment supply from upstream is higher. As a result, narrow floodplains form within the between confining features and bedrock, but tend to drape and bury the secondary confining features once the available accommodation space has been filled. While these drapes tend to be very thin,

The surface expression of the confining features is almost nonexistent. While Plainview perspectives may give the impression that these are alluvial rivers, field evidence indicates that these partly confined rivers have limited capacity to adjust [32]. The nature and extent to which human imprints are manifested along a river are dependent on its capacity to adjust and its sensitivity to change [17, 27]. In landscapes that contain significant antecedent control, either geological or climate induced, contemporary rivers may have limited capacity to adjust and be relatively resilient to human disturbance [33]. As such, the geomorphic imprint of human disturbance may be minimal or highly localised.

Fryirs et al. [24] documented the distribution of river change since European settlement in the upper Hunter catchment (NSW, Australia). They found that only localized adjustment to channels and floodplains had occurred in partly confined valleys and that the imprint of human disturbance has been relatively limited. Geological and climatic controls ensure that there is significant geomorphic memory in this old, slowly down wearing landscape [19] and that contemporary processes and forms are not always the result of current Climatic conditions or human-induced impacts.

CONCLUSION

Partly confined rivers are transitional between bedrock-controlled and fully alluvial rivers. Discontinuous floodplain pockets begin to form along these rivers. The range of river types formed within these valleys includes bedrock-controlled discontinuous floodplains and planform-controlled discontinuous floodplains. Three different types of partly confined river have been identified in the Harsin catchment. These form at particular positions on longitudinal profiles. The headwaters pattern of this river types is dependent on valley confinement and shape that acts as the primary confining features. In addition to this control, secondary confining features may be present. Various forms of fan, terrace, act as additional confining features inset against the bedrock valley margins. These antecedent controls dictate the ability of the contemporary river to adjust on the valley floor. Given that the inherited features are not readily reworked under contemporary flow regimes, this landscape contains significant geomorphic memory. Conditions set in the past continue to exert a key influence upon contemporary river character and behavior.

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