1.0 Introduction

Diverse fluvial geomorphology is centrally involved in river basin management, with particular contributions to river restoration and flood risk analysis (Newson & Large, 2006). The European Union Water Framework Directive (WFD) has highlighted a need to assess the quality of river ecosystems by protecting or rehabilitating high quality geomorphological systems from degradation (Herring et al., 2010). Following the Environment Agency’s, “River Wey Catchment Geomorphological Survey and Assessment” of the river Wey (Mant, Hooke & Duane 2001), a new study was required to analyse changes in sensitivity over the past 10 years. The current Environment Agency approach of qualitative sensitivity surveys lacks scientific validity and integration with freshwater ecology (Newson and Newson, 2000). This approach of recording objective opinions upon inspecting the river has therefore led to many restoration failures (Palmer et al., 2005). Bed-load sediment transfer is an essential element of fluvial geomorphology and has enabled more empirical analysis that have been useful for river management in the UK (Sear et al., 2003; Downs and Gregory, 2004) and by adopting a new approach of comparing bedload sediment transport rates with the current visual qualitative sensitivity measurements, there can be a more scientific approach to future restoration.

1.1 River Wey Catchment Geomorphological Survey and Assessment 2001 The “River Wey Catchment Geomorphological Survey and Assessment” of the River Wey (Mant et al, 2001) was commissioned by the Environment Agency Thames Region from Rivers and Coastal Environments Research (RACER) at the University of Portsmouth. The work was carried out from March – October 2000 and classified the River Wey and its tributaries into a standardised scale of geomorphological sensitivity (Fig.1) which is tested against a bedload sediment model throughout this report. The Study of the River Wey and its main tributaries covered an estimated 316km with reaches divided into lengths of around 500m defined by overall geomorphological homogeneity (Mant et al, 2001).

Statistical analysis of the report showed that the catchment was classified as 26% high sensitivity, 42% moderate sensitivity and 32% low sensitivity with high geomorphological sensitivity in upstream reaches and a large transfer of sand. Deposition in the upper catchment has created alterations of habitats with some gravel beds smothered by sand. Furthermore, in the lower catchment there is a need to periodically dredge to allow for navigation (Environment Agency, 2003).x

1.2 Description of Catchment

The River Wey catchment is situated primarily in Surrey with a total catchment area of 1007km2 (Environment Agency, 1998) and accounts for 10% of the catchment area of the Thames. The majority of the Wey catchment comprises a typical lowland river with a wide floodplain which runs through rural areas, with the principle land use being a mixture of arable, pasture and meadowlands with Alton, Farnham, Godalming, Guildford, Haslemere, Woking and Weybridge constituting the key urban areas (Mant et al, 2001).The North Wey rises from a chalk aquifer near Alton whilst the southern branch flows from lower greensand springs near Haslemere. The South of the catchment is dominated by Lower Greensand overlaying Weald Cay with a shallower gradient and a steep chalk outcrop near Guildford. In the North there is predominantly Tertiary clays, sands and gravel overlying London Clay which is characterised by heathlands (Environment Agency, 2008).

Special Areas of Conservation (SAC); Special Protection Areas (SPA); Ramsar sites, Sites of Special Scientific Interest (SSSI), National Nature Reserves and Areas of Outstanding Natural Beauty (AONB) cover a significant part of the catchment with ancient woodland and extensive areas of grassland along the river corridors (Environment Agency, 2008).

There is a strong spatial and temporal variance in riparian vegetation along the Wey with many banks lined with Willow, Alder and Beech and others dominated by nettles and brambles (Mant et al, 2001). Along the Wey a high variance in types and quantity of vegetation can be seen, with some managed areas with little bank colonisation and other areas inundated with fresh water reeds, indicating lower bedload sediment transport. This as well as invasive species such as Japanese Knotweed, Himalayan Balsam and diseases such as phytophthora affecting Alders, highlights the importance of an approach which properly quantifies the morphology and ecology of the river.

Much of the river has been subject to realignment for agricultural and urban purposes such as flood alleviation as well as for the Wey navigation and canals (Environment Agency, 2008). An effective identification of the sensitivity of different reaches is essential for management plans and for increasing morphological and ecological diversity.

1.4 Water Framework Directive

Anthropogenic activity has a fundamental impact on the character and behaviour of our fluvial systems (Gregory 2006). The Water framework Directive was adopted in 2000 and provides the policy behind the protection of water systems and has changed water management in the European Union by placing aquatic ecology at the base of management decisions (Herring et al, 2010). This framework provided the motive for the Mant, Hooke and Duane 2001 River Wey survey and is echoed in the rest of the UK and Sweden with an increased alacrity to tackle water quality issues with environmental measures (McLusky and Elliott, 2004).

Since the 1990s there has been a global increase in holistic environmental management, with countries tackling problems in river systems with a natural and social science approach (Apitz et al., 2006). On the other hand, the WFD’s practical implementation has been criticised by politicians and scientists (Moss, 2008, Dufour and Piegay, 2009) for a lack of data being collected on widespread pressures such as the complex hydrological and geomorphological (hydromorphological) processes outlined in the aims and objectives of this report. Furthermore, the timescale of the WFD’s goal of obtaining good ecology in all surface waters by 2027 is unrealistic, with a greater knowledge base needed to stop the degradation of fluvial systems by implementing successful restoration projects. (Herring et al, 2010).

1.5 Environment Agency River Sensitivity

The Environment Agency’s current standardised scale of a rivers geomorphological sensitivity to degradation is comprised of a subjective survey sheet as used in the 2001 River Wey study by Mant, Hooke and Duane. Sensitivity is a measurement of a systems resilience, which can be interpreted in a variety of ways; among ecologists it conveys a sustainable system with the ability to adapt to disturbance, whereas with engineers it is a river that responds well to flood events and provides buffers against climate change and land use pressures for humans (Folke, 2006). According to the WFD, fluvial and ecological assessments have to be grouped in order of their hydromorphological processes (Herring et al, 2010) and whilst highlighting that a highly sensitive river is predominantly wild with a wide range of natural characteristics such as sinuosity, pools, riffles, natural substrate and diversity of habitat (Mant Hooke and Duane, 2001), the EA system lacks scientific objectivity and integration with freshwater ecology (Newson and Newson, 2000).

1.3 Fluvial Geomorphology

The term fluvial is derived from the Latin word fluvius, meaning river. Fluvial Geomorphology is therefore the study of river processes, channel forms and the environmental forces which interact over a range of temporal and spatial scales on river ecosystems (Charlton 2008). Variability in landscape morphology such as discharge, slope and sediment supply is at the centre of what defines a river, with braided rivers for example, steep and sediment-abundant with a high-relief (Fryirs, and Brierley 2009). An empirical assessment of fluvial morphology is therefore more accurate and useful for the Environment Agency than the current approach. With diverse geomorphology in river systems being crucial in providing the support for rich aquatic habitats (Newson and Newson, 2000), there is a need to remove the disparity between the research of fluvial systems and subjective approach which is utilised by organisations such as the Environment agency (Newson and large, 2006).

The two most important concepts behind fluvial geomorphology are the conservation and sustainability of watercourses. With an increasing desire to protect watercourses in an economical and sustainable way, fluvial geomorphology plays an essential part in reducing undesirable consequences in the interventions of rivers (Maas and Brookes, 09). It is therefore an essential part of environmental impact assessment (EIA) and strategic environmental assessment (SEA) plans as pertaining to river and floodplain restoration and catchment/sediment management. Increasing understanding of the ways in which channel structure supports aquatic biota communities at different spatial and temporal scales should form a larger context for river rehabilitation and numeric modelling of river systems (Clifford et al., 2008).

1.6 Sediment Transfer Approach to Sensitivity

Fluvial geomorphological features of rivers are largely related to bed-load sediment transport rates, although this relationship has received little qualitative attention in the literature (Bridge 2003, Church, 2006). A failure to explore and transfer sediment transfer research into action has led to poor success rates for fluvial rehabilitation projects, with few creating ecological and sustainable improvements over the long term (Palmer et al., 2005). Furthermore, with scientific research into the ecology and physical processes of fluvial systems not geographically representative and usually limited to pristine upland rivers for scientific purposes (Graf, 2001), it is essential that these skills are utilised for river restoration schemes across the UK.

Alluvial channels such as those seen in areas of the river Wey which contain unconsolidated sediment, adjust their morphology by the erosion, carrying and re-depositing of bed material. These systems are in equilibrium when a stretch has the capacity to transport all of the sediment supplied from upstream without net deposition or erosion (Turowski, et al 2008). On the other hand, bedrock channel sections which have less ecological diversity, lack a continuous cover of alluvial sediments and exist only where bed-load transport is higher than the quantity of sediment available (Whipple, 2004).

Each river system is unique and should be managed with its specific forms and processes in mind (Brierley and Fryirs 2005). Similarly, with goals at various rehabilitation programs varying due to socioeconomic, cultural and ecological differences (Fryirs and Brierley, 2009) and naturalness seen as a more important measurement of what a river should be like, sediment transfer rates collected at highly sensitive and ecologically diverse streams may give a better empirical reference point for future development.

1.7 River morphology and Ecology

The bedload transport rates which are essential in understanding the river systems are calculated using stream power, critical streampower, flow depth and median grainsize. The way this translates to ecosystems is largely unknown, whether streams with a low transport rate and high deposition are more likely to be meandering with overbank flows and therefore have a greater ecological diversity and sensitivity, will be questioned in this report. Bed-load transport provides the major processes that governs river morphology and is vital for informed management decisions that affect a river’s function (Gomez, 2006). It therefore has a direct impact on ecology, with areas of sediment removal leading to the degradation of pools, riffles and gravel bars which are essential for the proliferation of salmon and lamprey eggs as well as protected species such as fresh water pearl mussels (SEPA, 2010). Furthermore, the artificial removal or deposition of sediment in river restoration schemes or damming projects can lead to sediment starvation further downstream, increasing erosion (Xu and Milliman 2008) and destabilising fluvial ecosystems. On the other hand, some argue that erosion is a desirable attribute of rivers and associate it with dynamic habitats that are crucial for ecological functions (Florsheim and Chin, 2008).

Nevertheless, there is however, a lack of empirical data on the long-term hydrogeomorphological scales required for assessing restoration and rehabilitation success (Hering et al., 2010) and alternatives to current management strategies are required. By linking geomorphological processes such as bed-load sediment analysis with ecological functions and sensitivity analysis, the data needed to create more sustainable river management can be achieved (Florsheim and Chin, 2008).

Aims and Objectives

The WFD has provided the policy for protection of rivers and scientific opinion has changed over recent years to one of understanding the importance of sustainable management of fluvial ecosystems and the supporting geomorphological processes (Downs and Gregory, 2004). With a wide range of socioeconomic, cultural and ecological (Fryirs and Brierley, 2009) pressures, as well as recent failures in fluvial rehabilitation schemes (Palmer et al., 2005) this report will test the Environment Agency’s subjective approach with a more scientific numerical approach to modelling river systems (Clifford et al., 2008). This disparity between the research of fluvial systems and the current subjective surveys (Newson and large, 2006) as well as a lack of regional scientific research into fluvial systems (Graf, 2001) has hindered the EA’s ability to integrate river sensitivity readings with restoration of freshwater ecology (Newson and Newson, 2000. Bed-load transport provides the major processes that govern river morphology (Gomez, 2006) and by geomorphologic studies such as bed-load sediment analysis, sustainable and ecological river management can be improved (Florsheim and Chin, 2008). This report will suggest bedload sediment transport as an alternative to the current sensitivity approach through the development of the following aim and objectives:

**Aim:**

* To calculate geomorphological sensitivity changes in the River Wey over the past 10 years, comparing this with rates of bed load sediment transport after periods of high and low rainfall, whilst critically assessing each technique.

**Objectives:**

* To collect observational data of 4 sites along the River Wey and measure their sensitivity using the Environment Agency’s sensitivity survey.
* To calculate bed-load sediment transport rates by finding critical streampower and streampower and applying them to the Bagnold Equation at the same 4 sites along the river Wey.
* To compare and contrast the bed-load sediment transport rates with sensitivity readings.
* To gather data of the components of bed load sediment transport rates from 4 sites after periods of high and low rainfall to calculate any differences.