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Interaction of Ground Water and Surface

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Abstract-

A transition zone develops in the lake bed or river bed or sea bed through which ground water and surface water interact. They both mix in a 'hyporheic zone' in a river where a particular type of flora and fauna are present. This mixing of ground water and surface water is induced by a pressure gradient created by the variation in the flow of surface water. This mixing zone depends upon the type of riverbed, flow of river, ground-water and surface water head. The paper will elaborate the causes of interaction of ground water and surface water.

Key words- Tamsa, river, interaction surface, water etc.

Interactions of Ground Water and Surface Water

Surface and Ground Water form a single hydrological system. Previous practice, however, has been to manage these resources in isolation. Clearly, an integrated approach is required to best manage what is effectively a single resource within many river-basin settings. Given below are the mechanisms and key processes that occur during groundwater/surface water interactions.

Concepts: Subsurface water, Water Table and Flow System

(A) Subsurface Water

Water occurs at two places below the surface Earth the unsaturated zone and the saturated zone. The unsaturated zone has water and air in the empty spaces (voids) between sand, clay, silt, etc. which cannot be drawn out. The water in upper part of this zone is used for plant processes. This water can evaporate into the environment either through transpiration or directly from soil water.

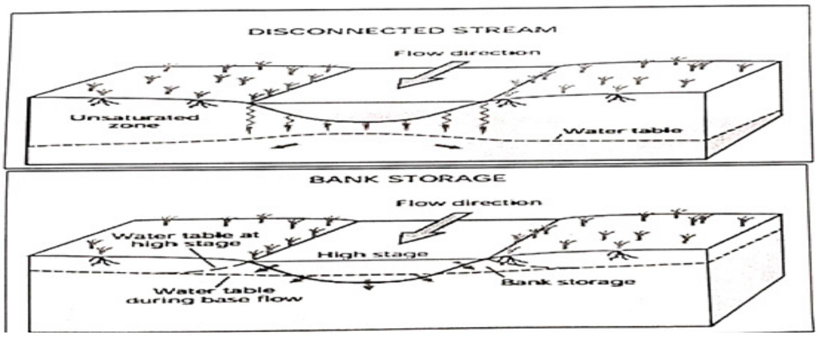

Figure 1.1: Different zones with water table

On the contrary, the saturated zone contains water in the empty spaces which is called Ground water. The upper surface of saturated zone is called Water Table. Water can be pumped out easily from below the water table as the pressure of water is high here.

(B) Water Table

Water present in the saturated zone is called Ground water, the upper surface of the saturated zone is called Water Table. The distance of the water table from the surface of land is not fixed everywhere. It also varies with seasons and from one year to another because the ground water actually depends upon the location, topography, climatic conditions and amount of precipitation in that area. Generally, the water table is near to the land surface near lakes, streams, wetlands, etc. We can measure the depth of the water table.

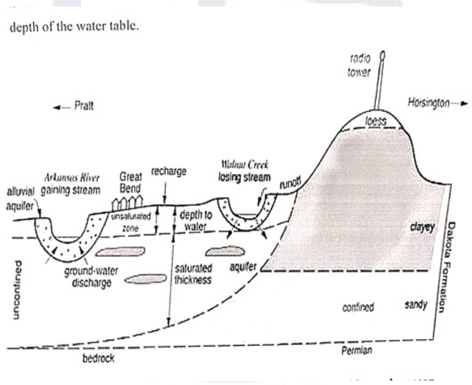

Figure 1.2: Depending upon the depth of the water table and season, transpiration taking place directly from ground water

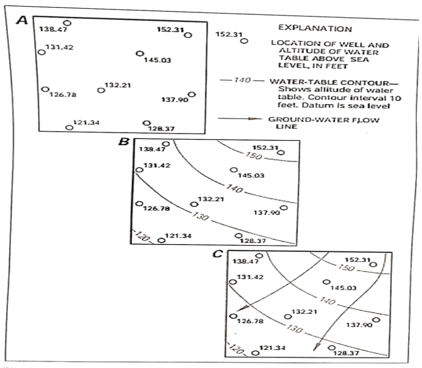

Figure 1.3: A = Wells with the attitudes of their water table shown
B = Contour maps of the water table
C = Direction of flow of ground water along the water table

A water table map can also be prepared which helps to know the course of flow of ground water at any place on the water table. The level of water table keeps on changing and depends upon the ground water recharge and discharge. Thus, a water table map is not always the same, instead it is only for that particular time.

(C) Flow system: Water recharge and discharge

A ground water basin is a closed 3-D flow system. In this system, water flows from the section where water table is recharged to areas where water table is discharged. Ground water moves downward with respect to the water table in recharge areas whereas it moves upwards as compared to the water table in discharge areas.

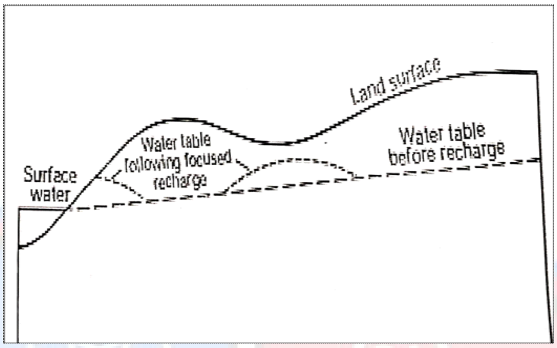

Figure 1.4: Recharge of Ground water

M Elines and discharge areas are shown by converging lines. However, Toth generalized three types of flow fields local, intermediate and regional flow systems (figure 1.5) though the flow of ground water is extremely slow in the absence of a hydraulic gradient. Out of these, the local flow systems are present at the least depth and interact the most with the surface water. Intermediate and regional flow systems are present below local flow systems.

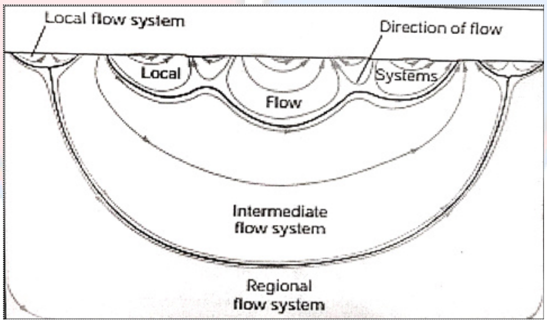

Figure 1.5: Local, Intermediate and Regional flow systems

As a whole, water present at greater depth usually has a higher concentration of chemicals present in it because the water there has a longer flow path and hence remains along with the subsurface material for an appreciable duration. Subsequently, when this water discharges, it can greatly affect and alter the chemical properties of water.

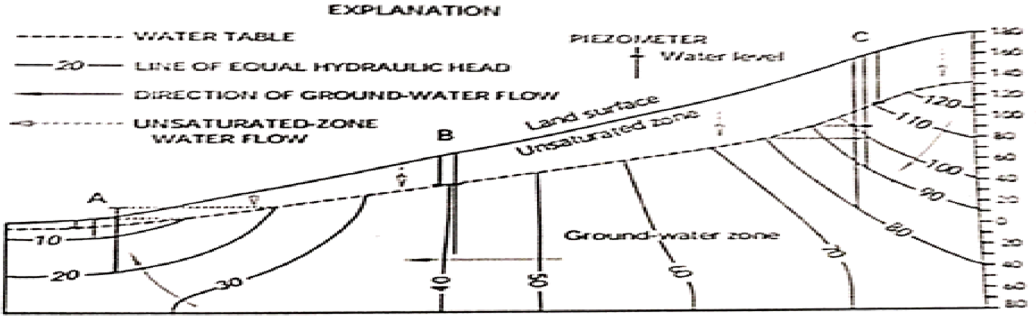

Figure 1.6 : Zone of upward, downward, lateral component of flow of ground water from piezometer data

(D) Interaction of Ground Water with different water bodies

(i) Interaction of Ground Water and Stream

The exchange of water in streams takes place by the inflow and outflow through streambed. At some places, they gain water and at some places they lose water. Ground water and streams interact with each other in any type of topography.

(ii) Interaction between ground water, lakes and reservoirs

Lakes, reservoirs, streams and other water bodies interact with ground water in basically a similar way though with certain differences. As compared to streams, in case of lakes, bank storage is not significant, water level does not keep on changing frequently and evaporation is more and has complex surface water and ground water interaction. This can be true for lakes in hostile and sandbank terrains. In addition, lake sediments frequently have higher volumes of organic deposits as compared to the streams. These inadequately porous organic deposits may affect the allocation of seepage and bio-geo chemical interactions among water and solutes. Reservoirs are manmade and resemble both streams and lakes in their properties.

(iii)Interaction between wetland and ground water

Wetlands present in depressions like lakes and streams interact with the ground water in same manner but those present on slopes, uplands, flat areas, riverine, coastal areas behave differently.

Hydrologic Cycle

The Hydrological cycle depicts the path and flow of water between surface water and ground water. This cycle helps to explain various hydraulic processes including distribution and flow of water between streams, wetlands, lakes, oceans (surface water) and water below the surface of the earth including soil water (ground water).

Distribution of precipitation, evaporation and transpiration is worldwide and depends upon the geological conditions and climate. Consequently, all the precipitated water doesn't go into the ocean, but most of this water goes into the subsurface and surface run off and hence loss of water to the atmosphere is reduced. The extent of individual factors of hydrological cycle varies effectively from place to place. For example, evapotranspiration varies between farms and nearby forest areas.

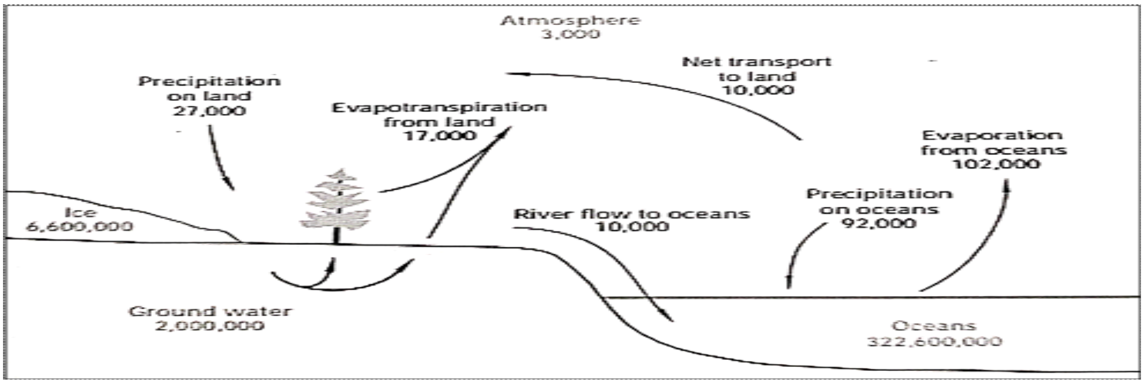

Figure 1.7: Four main pools of water on Earth and river flow to the oceans (Pools are in cubic miles and Fluxes are in cubic miles per year)

But the transport of ground water is not simple to recognize and explain. The ground water is recharged at the water table by infiltration of fallen rain or snow, etc. to the unsaturated areas and continues to flow till the ground water terminates at any stream or at some tube well. The flow time for the upper most unconfined aquifer varies from days to millennia depending upon the length of the flow path, ranging from few hundreds of feet to tens of miles.

Seepage of water is affected by the permeability and other geographical properties of any surface water bed, for example the type and pattern of sediments in the water body.

The Interface between Surface Water and Ground Water

A transition zone develops in the lake bed or river bed or sea bed through which ground water and surface water interact [1]. They both mix in a 'hyporheic zone' in a river [2] where a particular type of flora and fauna are present [3]. This mixing of ground water and surface water is induced by a pressure gradient created by the variation in the flow of surface water (Fig 1.8). This mixing zone depends upon the type of riverbed, flow of river, ground-water and surface water head [4]. The system is heterogeneous and the flow is continuous along the zone.

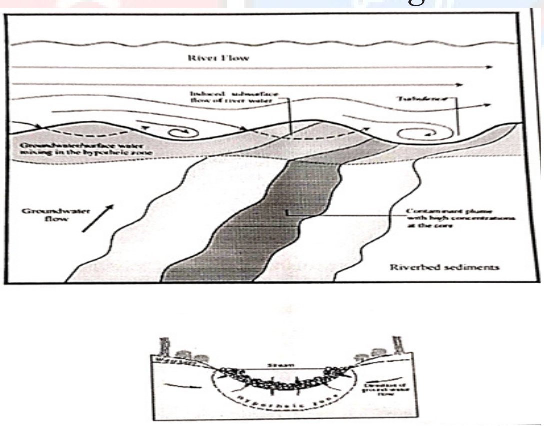

Figure 1.8 ; Lateral and Vertical Sections of a River Bed

Due to variations in concentration and environment throughout the transition zone"[5], there is a difference in the growth and distribution and chemical composition. Microbial, along with biological activities may lead to biodegradation of organic contaminants, reducing the level by several orders of magnitude in this zone. Here benthic invertebrates grow easily because of availability of nutrients in abundance. In addition, biological and chemical changes take place in compounds in transition zone [6]. Thus, this zone is significant from ecological point of view.

Hyphoreic organisms can thus show the effect of pollution. Surface water exchange along with storage in hyporheic zone influence the downstream nutrients and contaminants as the chemical and biochemical processes occurring in the zone are very fast. Thus, if the rate of ground water- surface water exchange is high, then there are significant changes in the quality of river water. [7]

The interaction between surface water bodies and ground water is multifaceted and also dependent on various factors such as topography, climate, geology and the location of the surface water body as compared to the flow system of ground water. [8, 9] Local, intermediate and/or regional ground water flows may discharge into surface waters (Figure 1.9) and surface water may on occasions recharge the ground water. [10, 11] Hence a reduction in flow or contamination in one will often affect the other. Woessner's stated that the ground water flow into a river channel is dependent on following factors. [12]

1. The distribution along with magnitude of hydraulic conductivities occurring within river channel and associated fluvial plains, sediment and underlying bedrock.
2. The relation of stages of river to the nearby ground water gradients.
3. The geometry and location of river channel in the fluvial plain.

Ground water is influent to the river channel when the head of ground water at the channel interface is higher than the river-stage, whereas, surface water is effluent from the channel when river- stage is upper than the ground water head. Ground water through-flow may arise when head of ground water is higher than the river stage on one bank but lower on the other." Ground water flow may also occur parallel to the river in which case only limited ground water/surface water exchange may occur.

During periods of high recharge, ground water 'mounding', i.e. rapid increase in head may occur in the thin unsaturated zone adjacent to surface-water bodies which may temporarily influence ground water, surface water interactions. A key reference by Winter et al. summarized the current understanding of interactions between surface and ground water and their effect on quality of water, water supply and the marine environment." A unifying frame work based on the concept of hydrologic landscapes is used to present conceptual models containing common features of ground water/surface water interactions, for example, in mountainous, riverine, glacial, dune, coastal and krast terrain.

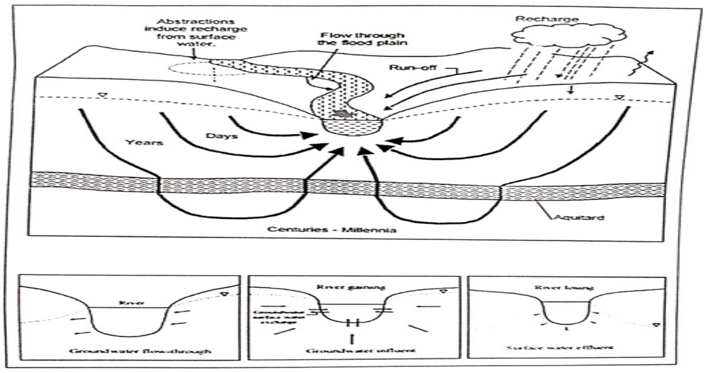

Figure 1.9 : Flow of Ground water to a River : A Conceptual Model

Evolution of water Chemistry due to surface water and ground water interaction

Many streams and rivers are polluted and since there is a water chemistry between surface water and ground water, it has become important to determine the type and extent of chemical reactions taking place in the hyporheic zone because of the concern that the polluted water of the stream will also pollute the ground water.

Water infiltered in shallow regimes react with gases in trivial ground water and unsaturated regions. This results in localized, short term, fast chemical changes which prevail for a lesser time period; for example - leaching of minerals and degradation of organic substances. But in deeper regimes slow changes take place which persist for a longer duration such as, ion-exchange of solutes and minerals.

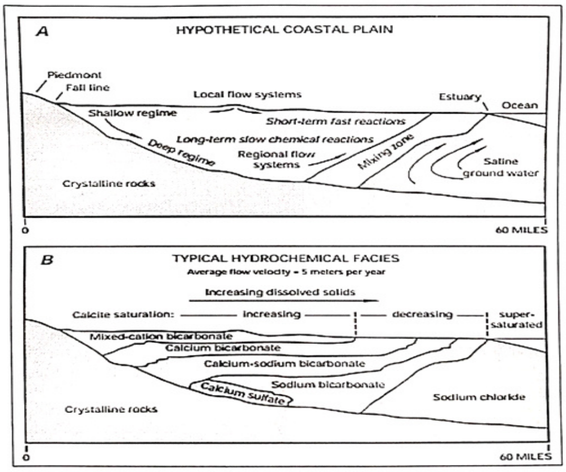

Figure 1.10 : (A) Relation between various types of rocks, ground water systems and salt water mixing

(B) Leeching of chemicals in ground water

Mixing of surface water and ground water in the hyporheic zone causes many chemical changes. When water penetrates into the stream bed, oxygen rich water inflows into the shallow regimes and results in enhanced biogeochemical changes (due to aerobic micro-organisms). At some places anaerobic micro-organisms are dominant in the subsurface. Anaerobic bacterial metabolic reactions run on consumption of nitrate, sulphate or other solutes as a source of oxygen. Due to these activities many solutes become very reactive in shallow ground water. These biogeochemical reactions occurring in hyporheic zone greatly influence the inflow of nutrients, contaminants and many chemicals.

In wetlands and lakes also, typical biogeochemical processes take place. Chemical changes taking place in ground water, magnitude of interaction between subsurface and surface water and their direction influences the leaching of water solubles into the surface water and wetlands. Precipitation is the principal source of such chemicals if the ground water and surface water interface is not sufficiently large. In such condition input of soluble is small in surface water. But if ground water and surface water interface is large, then, chemical input is also large and consequently, production of plants and algae through the wetland is also big. When these organisms are decomposed, dissolved oxygen is consumed. If Consumption of oxygen is extreme, it is lethal for the aquatic flora and fauna.

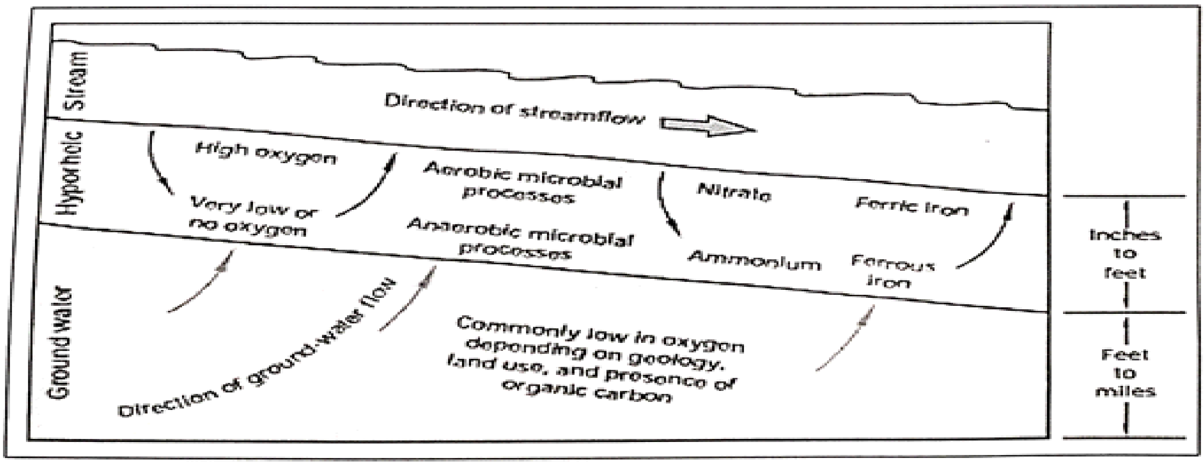

Figure 1.11: Chemical changes and Microbial activities going on in water

Outflow and inflow of surface water affects the concentration of chemicals in the water sources. If surface water flow flushes the wetland, concentration of nutrients is decreased in water otherwise retention of chemicals and nutrients occurs.

The original composition of ground water due to the recharge process and presence of minerals is changed by the presence of pollutants like hydrocarbons, toxic metals, pathogens, etc. in the underground environment.

Conant suggested various parameters to ascertain the harmful effects of subsurface pollutant concentration on river water. These are:

1. Chemical as well as physical properties of pollutants
2. Time period of contamination and its source
3. Method of contamination (horizontal transfer diffusion method)
4. Types of physical and chemical changes (reversible or irreversible)

Transportation and toxicity of pollutants depend upon their physical and chemical characteristics. The contaminant may move through surface as pure liquid or may be in gaseous phase as dissolved phase in particulate form or may be attached to colloids. Soluble compounds easily go into the ground-water resulting in higher contaminant percentage. Compounds with low solubility are present in lesser amounts but may retain for a long time in ground water. [13] The main path by which underground pollutants can influence river water quality is likely through advective transfer in solution phase in ground water. Discharge of industrial effluents and agriculture waste containing pesticides and fertilizers etc. are the primary point sources of ground water contamination. These point sources lead to narrow plumes which may migrate with ground water flow and can ultimately discharge into surface water (Figure 1.12).

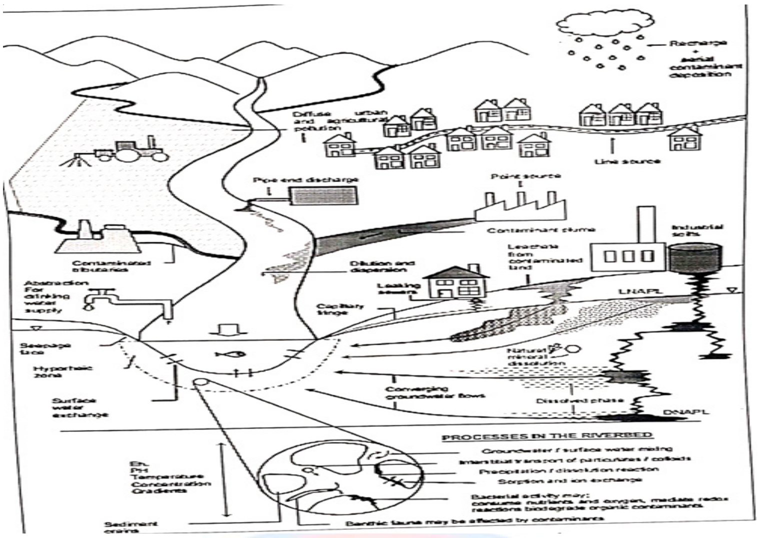

Figure 1.12 Input of Pollutants in a river

In USA, more than 75% of the contaminated land categorized under the Government's 'superfund' sites lie within 0.5 miles of a surface water body and more than half had an impact on surface water in some way. The initial contaminant concentration in the ground water will depend on the mass and distribution of the contaminant in the source area, the rate of ground water flow and the physical, chemical, biological processes controlling contaminant dissolution. Contaminants derived from the land surface may take a considerable time to enter the ground water if a large unsaturated zone is present.

Ground water contaminant concentrations in the source area may vary with time. Contaminant concentration within the ground water will be modified en route to, and across, the ground water/surface water interface. Dispersion will result in spreading and mixing of the contaminant plume with cleaner ground water. However, lateral dispersion within an aquifer is generally low and the plume remains narrow relative to its length, the highest contaminant concentrations being within the central zone. When the plume reaches the hyporheic zone, more turbulent conditions are likely to exist as the ground water mixes with the surface water and is ultimately diluted in the surface water column. During transport, the contaminants may undergo reversible reactions such as adsorption, precipitation, dissolution and ion-exchange and non- reversible reactions such as biodegradation. Reactions may be reversible only under certain conditions. For example desorption of heavy metals occurs under conditions of low pH, and therefore, contaminants may be effectively removed from the system until conditions change.

The types of reactions that occur are dependent on the local conditions and these may vary considerably along the contaminant flow path from the source area, through the aquifer to the interface. Relative composition and transport of contaminants between ground and surface water through interface is governed by the following phenomenon.

1. Bacterial action significantly affects the chemical reactions by acting as a catalyst during nitrate and sulphate reduction and directly degrading some organic compounds. The ground water/ surface water interface often has high nutrient content and anoxic conditions which are conducive to bacterial action.

2. Adsorption of contaminants to sites on the surrounding aquifer material. This reaction is generally reversible in which case it will not alter the total mass flux of the contaminants but it may significantly retard their transport allowing extra time for other processes to occur such as biodegradation. For organic contaminants, the degree of sorption is often proportional to the content of organic carbon which is generally much higher in the river bed sediments relative to the surrounding geology. For inorganic contaminants, clay minerals, organic matter and oxides/ hydroxides all have a sorption and exchange capacity which may retard contaminant transport."

3. Rapid changes in pH, EC and mixing of waters of significantly differing concentrations occur across the ground water/ surface water interface. Ground water chemistry which may have been in equilibrium will adjust rapidly to the new conditions, perhaps leading to sudden mineral precipitation. Iron Oxides are a common example of precipitation occurring when acidic, oxygen- poor ground water mixes with higher pH, more highly oxygenated surface waters.

Contaminant movement and transformation across the ground water / surface water interface are poorly understood. In light of this a workshop was held to summarize the existing knowledge based on the interface of surface water and ground water and to set some action plan to understand the effect of contaminated groundwater discharge through it. The proceedings of this workshop provide a key reference on this subject area (Environment Protection Agency U.S, 2000). It is predicted that by 2010, half the world's population of 6500 million will live in towns or cities, and that much of the urban growth will be in developing countries. Unfortunately, urban growth is often associated with degradation of water quality which limits the usefulness of both groundwater and surface water resources. The occurrence of contaminated groundwater related to urbanization is well known, both in the U. K. and abroad. 22-24 Likewise, the occurrence of poor quality urban surface waters is extremely common. 2526 However, urban ground water and surface water interactions are not well understood. For water managers and scientists, the study of this interaction is inevitable.

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