Lecture Note of Environmental Geotechnique (Sub. Code PCI8J001)

Session - 2018-19 (Summer)

Module - I

Definition

- An area of engineering, which has emerged from a confluence of geotechnical engineering and environmental engineering, dealing with solution for protection of subsurface environment as well as public health and promotion of sustainable developement.

- It mainly deals with prevention, detection and control of ground pollution and subsurface pollution as well as remediation of degraded land or contaminated sites.

Subsurface Contamination

Air, Water and Ground pollution

- Air pollution: disperses away with the wind

- Water pollution: flows away during high run-off in the monsoons

- Ground pollution: Stays in the soil or moves slowly with ground water.

Gaseous, Liquid and Solid waste

- Gaseous waste : Treated by air pollution Control devices; Produces Solid waste (eg. ESPs produce ash)
- Liquid waste : Treated by waste water treatment devices; produces Solid waste (eg. ETPs produce Sludge)
- Solid waste : Recycled or processed & reused or disposed on land (with/without treatment eg. MSW)

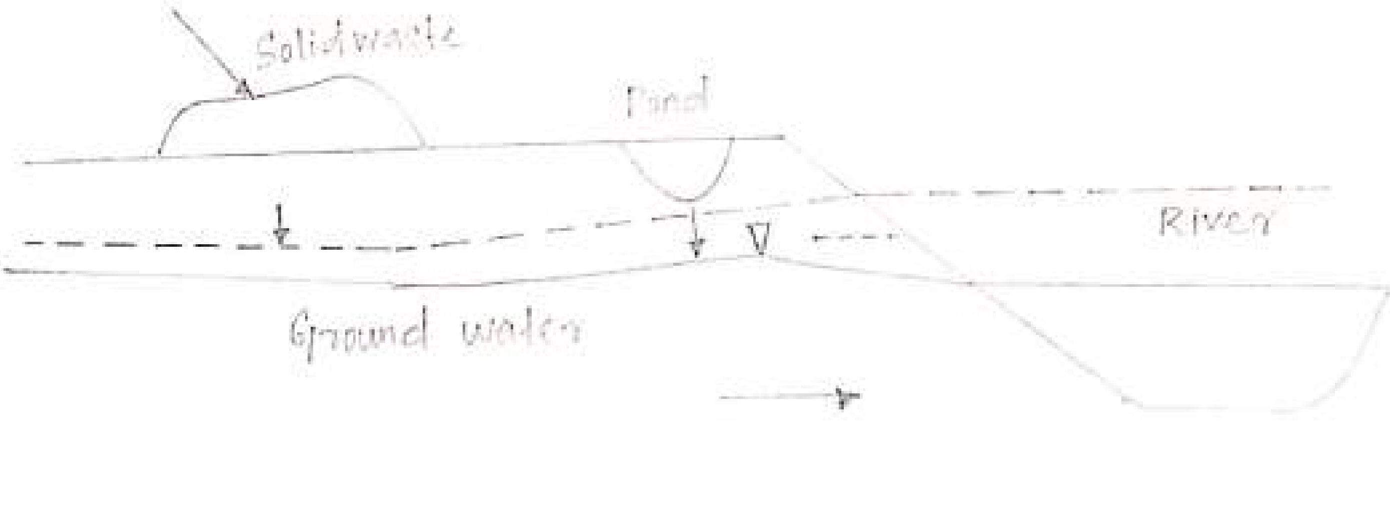
Interdisciplinary Area

- Geotechnical Engineers
- Environmental Engineers
- Geologists, hydrologists
- Geochemists, soil Scientists
- Agricultural Engineers
- Mining Engineers
- Chemical and biotech Engineers

Sources of Contamination

- Solids and liquids
  - Stored or transported on the ground or beneath the ground
  - in dumps, impoundments, drains, channels pipelines, tanks, drums etc
- Municipal sources, Industrial sources, Agricultural sources, Mining sources, Thermal power plants, Others

Subsurface Contamination



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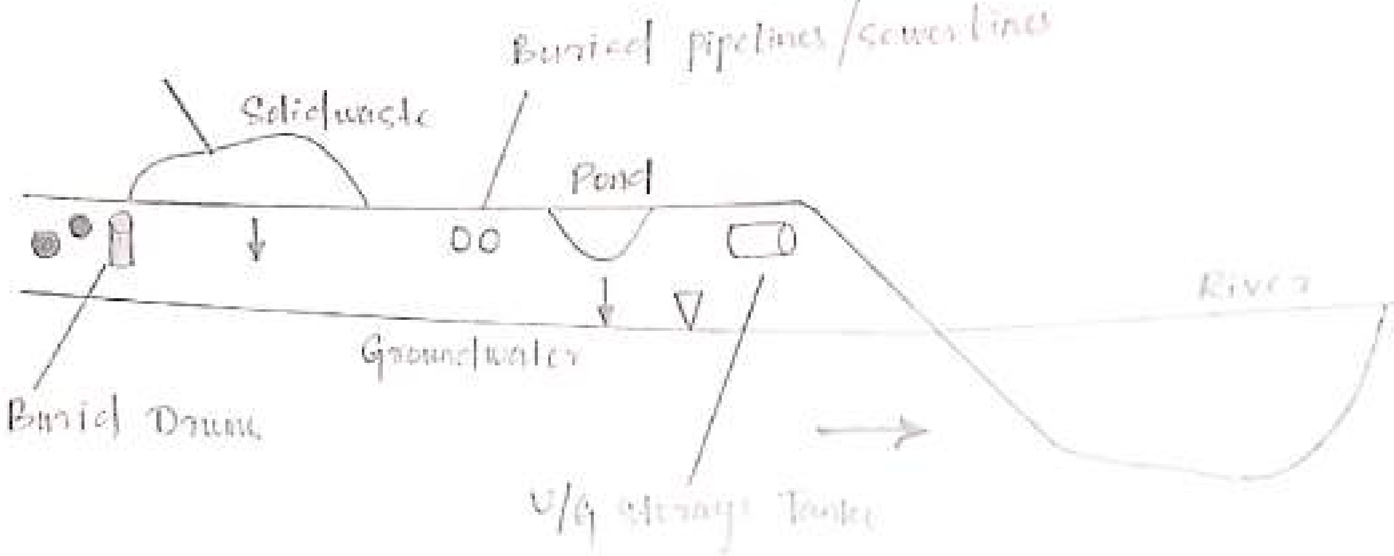
Subsurface Contamination



Municipal Sources

- Garbage Dumps or MSW Dumps or Unlined Sanitary Landfills
- Municipal Waste Water or sewage applied to land
- sewage sludge spread on ground
- Septic tanks
- Leaking Sewer lines

Industrial Sources

- Industrial Solid Waste generated by manufacturing processes
- ETP sludge — Effluent Treatment Plant sludge
- Liquid waste water, processing water, cooling water stored in ponds, impoundments, underground tanks
- Leaking pipelines and tanks

TSDF
Central storage and disposal facility affects subsurface environment.

Agricultural Sources

- Fertilizers & soil Ammendments
- Pestisides
- Animal waste from milk producing and meat producing units
- Food processing units → equal to industrial units (as they have got chemical processing or biochemical processing units)

Mining Sources

- Mine overburden (huge mounds) — 2km × 2km × 100m deep mining site
- Mine tailings - lead, zinc, copper, iron, gold uranium etc. (large quantity slurry wastes) — some residual metals 0.1 to 0.2%
- Mine processing liquid waste — metals hazardous

Thermal Power Plants

- Cool Ash (large quantity slurry waste)
  80 to 100 ponds in working

Million tons of accumulated.

Others

- Spills —
- Stockpiles —
- Lagoons —
- Injection wells —
- Buried drums —
- Indiscriminate disposal —
- Surface discharges —

Pathways

- Gaseous route: methane, carbon dioxide VOCs, other gases
- Air borne route: fine particles, odour, smoke
- Surface water route: Leachate, leaking liquids
- Ground water route: Leachate, leaking liquids
- physical erosion route: suspended solids

Receptors

- Nearby habitat and ecosystem
- Humans through drinking water (surface & ground water), recreational activities, air intake
- Domestic animals through drinking water
- Crops through irrigation, root uptake
- Industry through surface water and ground water usage
- others

Impact

- Larger the source
- Shorter the pathway
- More the receptors
- Greater is the impact

1.1.1 Types of Geosynthetics

There are eight types of geosynthetics: (1) geotextiles, (2) geogrids, (3) geonets, (4) geomembranes, (5) geosynthetic clay liners, (6) geopipe, (7) geofoam, and (8) geocomposites. They are shown in Figure 1.1 and are discussed next.

Geotextiles. Geotextiles (see Section 1.3 and Chapter 2) form one of the two largest groups of geosynthetics described in this book. Their rise in growth during the past 25 years has been nothing short of extraordinary. They are indeed textiles in the traditional sense, but they consist of synthetic fibers rather than natural ones such as cotton, wool, or silk. Thus biodegradation and subsequent short lifetime is not a problem. These synthetic fibers are made into flexible, porous fabrics by standard weaving machinery or are matted together in a random nonwoven manner. Some are also knitted. The major point is that geotextiles are porous to liquid flow across their manufactured plane and also within their thickness, but to a widely varying degree. There are at least 100 specific application areas for geotextiles that have been developed; however, the fabric always performs at least one of four discrete functions: separation, reinforcement, filtration, and/or drainage.

Geogrids. Geogrids (see Section 1.4 and Chapter 3) represent a rapidly growing segment within the geosynthetics. Rather than being a woven, nonwoven, or knitted textile fabric, geogrids are plastics formed into a very open, gridlike configuration—i.e., with large apertures between individual ribs in the machine and cross machine directions. Geogrids are formed in various ways: (1) stretched in one or two directions for improved physical properties, (2) made on weaving or knitting machinery by standard and well-established methods, or (3) made by bonding rods or straps together. There are many application areas, however, and they function almost exclusively as reinforcement materials.

Geonets. Geonets, called *geospacers* by some (see Section 1.5 and Chapter 4), constitute another specialized segment within the geosynthetics area. They are formed by a continuous extrusion of parallel sets of polymeric ribs at acute angles to one another. When the ribs are opened, relatively large apertures are formed into a netlike configuration. Their design function is completely within the drainage area where they are used to convey liquids of all types.

Geomembranes. Geomembranes (see Section 1.6 and Chapter 5) represent the other largest group of geosynthetics described in this book, and in dollar volume their sales are greater than that of geotextiles. Their growth in the United States and Germany was stimulated by governmental regulations originally enacted in the early 1980s. The materials themselves are relatively thin, impervious sheets of polymeric material used primarily for linings and covers of liquid- or solid-storage facilities. This includes all types of landfills, reservoirs, canals, and other containment facilities. Thus the primary function is always containment as a liquid or vapor barrier or both. The range of applications, however, is great, and in addition to the environmental area, applications are rapidly growing in geotechnical, transportation, hydraulic, and private development engineering.

Geosynthetic Clay Liners. Geosynthetic clay liners (GCLs) (see Section 1.7 and Chapter 6) are an interesting juxtaposition of polymer and natural soil materials. They are rolls of factory-fabricated thin layers of bentonite clay sandwiched between two geotextiles or bonded to a geomembrane. Structural integrity of the composite is obtained by needle-punching, stitching, or physical bonding. GCLs are used as a composite component beneath a geomembrane or by themselves in environmental and containment applications as well as in transportation, geotechnical, hydraulic, and various private development applications.

Geopipe (aka Buried Plastic Pipe). Geopipe, or buried plastic pipe (see Section 1.8 and Chapter 7), is perhaps the original geosynthetic material still available today. This orphan of typical engineering curricula is included here because of an obvious awareness that geopipe is being used in all aspects of geotechnical, transportation, environmental, hydraulic, and private development engineering most often with little design and testing, attributable to a general lack of formalized training. The critical nature of leachate collection pipes coupled with high compressive loads makes geopipe a bona fide member of the geosynthetics family and one that is focused completely on the drainage function.

Geofoam. Geofoam (see Section 1.9 and Chapter 8) is a product created by polymeric expansion process resulting in a "foam" that consists of many closed but gas-filled cells. The skeletal nature of the cell walls is the unexpanded polymeric material. The resulting product is generally in the form of large, but extremely light, blocks that are stacked side-by-side, providing lightweight fill in numerous applications. Although the primary function is dictated by the application, separation is always a consideration and geofoam will be included in this category rather than creating a separate one.

Geocomposites. Geocomposites (see Section 1.10 and Chapter 9) consist of a combination of geotextiles, geogrids, geonets, and/or geomembranes in a factory-fabricated unit. Also, any one of these four materials can be combined with another synthetic material (e.g., deformed plastic sheets or steel cables) or with soil. For example, a geonet with geotextiles on both surfaces and a GCL consisting of a geotextile/bentonite/geotextile sandwich are both geocomposites. This exciting area brings out the best creative efforts of the engineer, manufacturer, and contractor. The application areas are numerous and growing steadily. They encompass the entire range of functions previously listed for geosynthetics: separation, reinforcement, filtration, drainage, and containment.

Geo-Others. The general area of geosynthetics has exhibited such innovation that many systems defy categorization. For want of a better phrase, *geo-others* describes items such as threaded soil masses, polymeric anchors, and encapsulated soil cells. As with geocomposites, the primary function of geo-others is product-dependent and can be any of the five major functions of geosynthetics. These materials will be discussed in those chapters that they are most closely related to, or in Chapter 9 on the basis of their primary function.

1.1.2 Organization by Function

The juxtaposition of the various types of geosynthetics just described with the primary function that the material is called upon to serve allows for the creation of a matrix that will be used throughout this book. In essence, this matrix is the "scorecard" for understanding the entire geosynthetic field and its design-related methodology. Table 1.1 illustrates the primary function that each of the geosynthetics can be called upon to serve. Note that these are primary functions, and in many (if not most) cases there are secondary functions, and perhaps tertiary ones as well. For example, a geotextile placed on soft soil will usually be designed on the basis of its reinforcement capability, but separation and filtration might certainly be secondary and tertiary considerations. A geomembrane is obviously used for its containment capability, but separation will always be a secondary function.

The greatest variability from a manufacturing and materials viewpoint is the category of geocomposites. The primary function will depend upon what is actually created, manufactured, and installed.

Note that Table 1.1 will be constantly referred to throughout this book. It will clearly identify each geosynthetic material vis-à-vis the primary function (usually by application) that is being served.

1.1.3 Market Activity

To say that the geosynthetic market activity, as indicated by sales volume, is strong is decidedly an understatement. All existing application areas are seeing constant growth, albeit at different rates. Current geosynthetics growth is approximately 5% in

TABLE 1.1 IDENTIFICATION OF THE USUAL PRIMARY FUNCTION FOR EACH TYPE OF GEOSYNTHETIC

Type of Geosynthetic (GS)	Primary Function					Chapter in Book
	Separation	Reinforcement	Filtration	Drainage	Containment	
Geotextile (GT)	✓	✓	✓	✓		2
Geogrid (GG)		✓				3
Geonet (GN)				✓		4
Geomembrane (GM)					✓	5
Geosynthetic Clay Liner (GCL)					✓	6
Geopipe (GP)				✓		7
Geofoam (GF)	✓					8
Geocomposite (GC)	✓	✓	✓	✓	✓	9

Note: This table will be referred to in every chapter of this book.

TABLE 1.8 MAJOR APPLICATIONS OF GEOTEXTILES

Separation of Dissimilar Materials

- Between subgrade and stone base in unpaved roads and airfields
- Between subgrade and stone base in paved roads and airfields
- Between subgrade and ballast in railroads
- Between landfills and stone base courses
- Between geomembranes and soil drainage layers
- Between foundation and embankment soils for surcharge loads
- Between foundation and embankment soils for roadway fills
- Between foundation and embankment soils for earth and rock dams
- Between foundation and encapsulated soil layers
- Between foundation soils and rigid retaining walls
- Between foundation soils and flexible retaining walls
- Between foundation soils and storage piles
- Between slopes and downstream stability berms
- Beneath sidewalk slabs
- Beneath curb areas
- Beneath parking lots
- Beneath sport and athletic fields
- Beneath precast blocks and panels for aesthetic paving, e.g. hardscaping
- Between drainage layers in poorly graded filter blankets
- Between various zones in earth dams
- Between old and new asphalt layers

Reinforcement of Weak Soils and Other Materials

- Over soft soils for unpaved roads
- Over soft soils for airfields
- Over soft soils for railroads
- Over soft soils for landfills
- Over soft soils in sport and athletic fields
- Over karst and thermokarst areas
- Over unstable landfills as closure systems
- For lateral containment of railroad ballast
- To wrap soils in encapsulated fabric systems, e.g. geotextile tubes
- To construct fabric-reinforced walls
- To reinforce embankments
- To aid in construction of steep slopes
- To reinforce earth and rock dams
- To reinforce stacked gabions
- To reinforce stacked geofoam
- To stabilize slopes temporarily
- To halt or diminish creep in soil slopes
- To reinforce jointed flexible pavements
- As basal reinforcement over soft soils
- As basal reinforcement over karst areas
- As basal reinforcement over thermokarst areas
- As basal reinforcement between deep foundation caps
- To bridge over cracked or jointed rock
- To hold graded-stone filter mattresses
- As a substrate for articulated concrete blocks and block mattresses
- To stabilize unpaved storage yards and staging areas
- To anchor facing panels in reinforced earth walls
- To anchor concrete blocks in retaining walls
- To prevent puncture of geomembranes by subsoils
- To prevent puncture of geomembranes by landfill materials or stone base
- To create more stable side slopes due to high frictional resistance
- To contain soft soils in earth dam construction
- For use in membrane-encapsulated soils
- For use in in-situ compaction and consolidation of marginal soils
- To bridge over uneven landfills during closure of the site
- To aid in bearing capacity of shallow foundations

Filtration (Cross-Plane Flow)

- In place of granular soil filters
- Beneath stone base for unpaved roads and airfields
- Beneath stone base for paved roads and airfields
- Beneath ballast under railroads
- Around crushed stone surrounding underdrains
- Around crushed stone without underdrains (i.e., French drains)
- Around perforated underdrain pipe
- Around stone and perforated pipe in tile fields
- Beneath landfills that generate leachate
- To filter hydraulic fills
- As a silt fence
- As a silt curtain
- As a snow fence
- As a flexible form for containing sand, grout, or concrete in erosion control systems
- As a flexible form for reconstructing deteriorated piles

(continued)

TABLE 1.8 (continued)

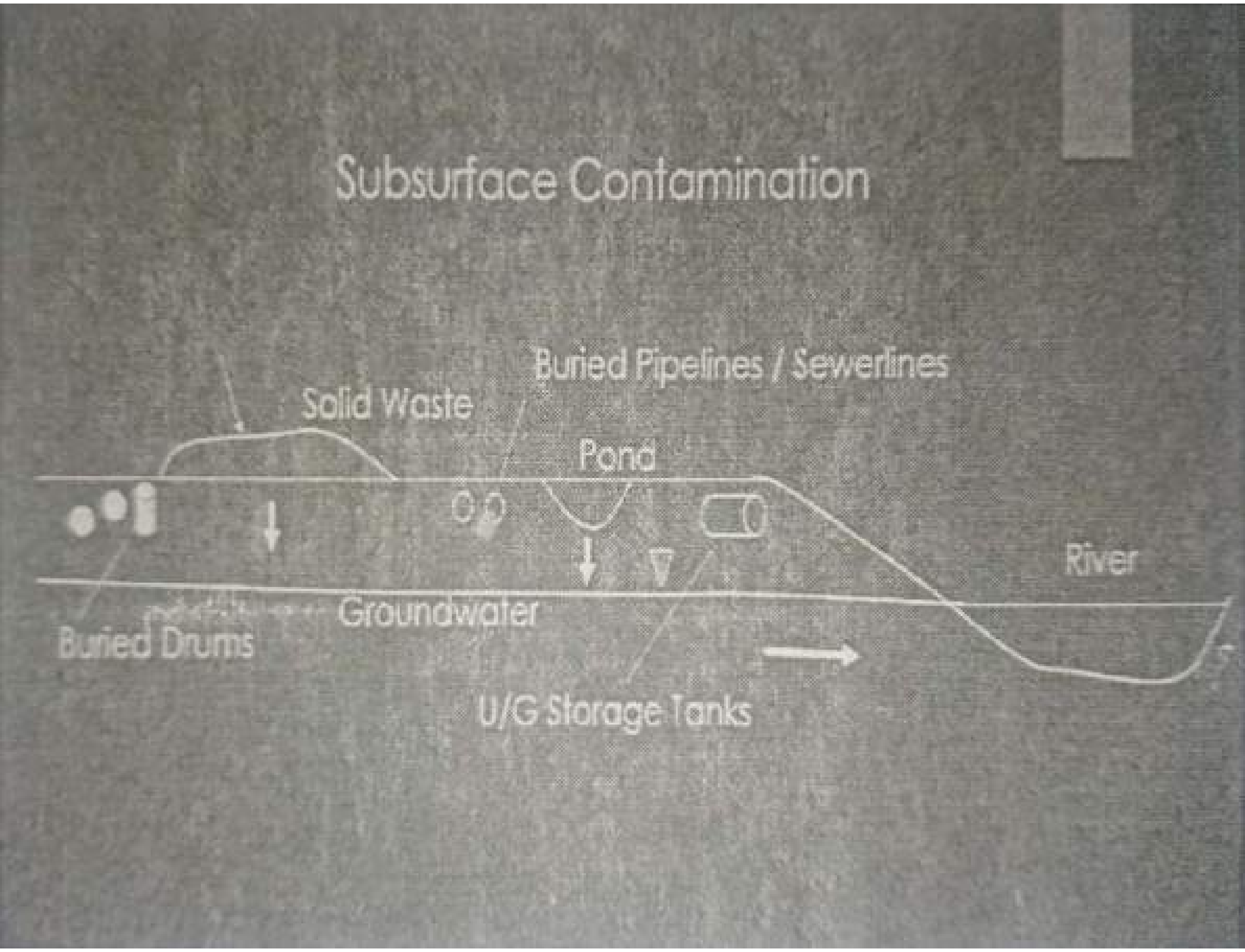
- As a flexible form for restoring underground mine integrity
- As a flexible form for restoring scoured bridge pier bearing capacity
- To protect chimney drain material
- To protect drainage gallery material
- Between backfill soil and voids in retaining walls
- Between backfill soil and gabions
- Around molded cores in fin drains
- Around molded cores in wick, sheet and edge drains
- Against geonets to prevent soil intrusion
- Against geocomposites to prevent soil intrusion
- Around sand columns in sand drains
- Around porous tips for wells
- Around porous tips for piezometers
- As a filter beneath stone riprap
- As a filter beneath precast blocks

Drainage (In-Plane Flow)

- As a chimney drain in an earth dam
- As a drainage gallery in an earth dam
- As a drainage interceptor for horizontal flow
- As a drainage blanket beneath a surcharge fill
- As a drain behind a retaining wall
- As a drain at the base of a retaining wall
- As a drain beneath railroad ballast
- As a water drain beneath geomembranes
- As an gas drain beneath geomembranes
- As a drain beneath sport and athletic fields
- As a drain for roof gardens
- As a pore water dissipator in earth fills
- As a replacement for sand or wick drains
- As a capillary break in frost-sensitive areas
- As a capillary break for salt migration in arid areas
- To dissipate seepage water from exposed soil or rock surfaces

Sources of Contamination

- Solids and Liquids,
  - stored or transported on the ground or beneath the ground
  - in dumps, impoundments, drains, channels, pipelines, tanks, drums etc
- Municipal sources, Industrial sources, Agricultural sources, Mining sources, Thermal power plants, Others


Subsurface Contamination
Buried Pipelines / Sewerlines
Solid Waste
Pond
River
Groundwater
Buried Drums
U/G Storage Tanks

Municipal Sources

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