sustainability

MDPI

Supplementary Material

Suitability zoning for sustainable drainage systems (SuDSs): Application in a basin in southern Brazil

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Table S1. Unconsolidated materials and basic descriptions.

Unconsolidated materials	Basic description
Transported—Alluvium	They occur in discontinuous layers with texture variation, thicknesses that can vary from 1 to 10 m and covering the residual unconsolidated materials. There are layers with significant percentages of organic matter and with a high compressibility index. They occur mainly associated with the main channel of the basin.
Transported—Silty-sand	This type covers the residual unconsolidated materials from the Itaqueri and Serra Geral formations, and even sandy-transported in specific sites. It occurs in a small portion of the basin, but in an area that is currently urbanized.
Transported—Sandy	These sediments occur in a large part of the basin and cover residual unconsolidated materials from the Itaqueri and Serra Geral formations with thicknesses that can vary from centimeters to 20 meters.
Residual from Itaqueri Formation	The residual unconsolidated material (soil, saprolite, weathered rock and unweathered rock) from Itaqueri Formation varies according to the outcropping lithology (sandstones, siltstones, claystones, conglomerates) resulting in regoliths with different textural characteristics, from sandy to clayey. The lithologies can have some layers with carbonate cement. The thickness of the regolith is predominantly less than 5 m.
Residual from Serra Geral Formation	The regolith consists of layers of unconsolidated materials with very different characteristics (soil, saprolite, weathered rock and unweathered rock), with total thicknesses less than 10m, predominantly less than 5m, and saprolites can contain varying amounts of minerals such as smectites and/or interstratified minerals.
Residual from Botucatu Formation	The residual unconsolidated materials (soil, saprolite, weathered rock and unweathered rock) developed from low-cemented sandstones have a high degree of homogeneity and continuity, are porous (porosity> 50%) and can consist of more than 90% of grain sand size.

Table S2. Geological and geotechnical characteristics of unconsolidated material units.

Component	Attributes	Parameters	Dimension	Categories			
				Favorable	Moderate	Severe	Restrictive
Relief	Slope inclination	Classes/ Categories	%	1–10	10–20	20–30	>30
	Channel frequency		Channel/ km²	<1	1–3	3–5	>5
	Slope length	Measured between the watershed limit and the thalweg	m	>500	300–500	200–300	<200
Unconsolidated materials	Regolith profile	Description based on variability		Homogenous and continuous	-	-	Heterogeneous and discontinuous
	Layer thickness	Surface layer	m	>5	3–5	2–3	<2

	Texture	Grain size distribution	%	Sandy with less than 30% of fines	Sandy with 30 and 50% of fines	Silt plus Clay between 50 and 70%	Silt plus Clay >70%
	Permeability	Hydraulic conductivity	cm/s	$>10^{-3}$	10^{-3}–10^{-4}	10^{-4}–10^{-5}	$<10^{-5}$
	Porosity	-	%	>50	45–50	40–45	<40
	Mineralogy	Clay Minerals (categories to estimate the potential for swelling)	Mineral	No	Kaolinite, Gibbsite, Illites	Smectites, Inter-stratified minerals < 3%	Smectites, Vermiculites, Interstratified minerals
		Clay Minerals (categories for estimating the magnitude of the Retardation factor)	Mineral	Smectites, Vermiculites, Interstratified minerals	Smectites, Interstratified minerals < 3%	Kaolinite, Gibbsite, Illites	No
		Reactive and soluble minerals	Mineral	No	No	Sulfides, Carbonates <0.5%	Sulfides, Carbonates
	Boulders	Size Frequency Depth		No	Small, few, shallow or on the ground surface	Large, few, shallow or on the ground surface	Many boulders with varying sizes and, at varying depths
	pH	-		5–7.5	7.5–8.5		>8.5
	Electrical conductivity	-	dS/m	<1	1–4	4–6	>6
	Exchangeable Sodium Percentage	-	%	<5	5–10	10–15	>15
	Organic material	-	%	>3	2–3	1–2	<1
Bedrock	Lithotype	-		High porosity			Low porosity
	Rockhead depth	-	m	>10	5–10	3–5	<3
	Mineralogy	Clay mineral		Kaolinite, Gibbsite,	Illites	Smectites < 3%	Smectites, Vermiculites
		Reactive and soluble minerals		No	No	Percentage <1%	Sulfides, Carbonates
	Permeability	Hydraulic conductivity	cm/s	$>10^{-3}$	10^{-3}–10^{-4}	10^{-4}–10^{-5}	$<10^{-5}$
	Fractures	Aperture	cm	0.02–0.05	>0.05	0.01–0.02	<0.01
		Frequency	Fractures/m	>3	2–3	1–2	1
		-	Jv (volumetric joint count)	>15	10–15	3–10	<3
Groundwater	Groundwater level/ Seasonality	-	m	>10	5–10	3–5	<3
	Flow direction	Hydraulic gradient		>0.01	0.005–0.01	0.001–0.005	<0.001
	pH	-		5.5–7.5	7.5–8.5		>8.5
	Electrical conductivity	-	dS/m	<0.5	0.5–3	3–5	>5
Flooding due to groundwater level rising	Groundwater flooding (Saturation Excess Overland Flow)	Evidence/ vestiges/ Presence of surface of hydric diffraction	-	No	No	Potential	Occur
Anthropogenic aspects	Made-Ground	Excavated geological materials, tailings and wastes deposited on the land surface	-	No	No	Occur	Occur
	Worked ground	Excavated land for various purposes, such as aggregate sources	-	No	Abandoned quarries	Occur	Occur

	Infilled	Excavated and subsequently infilled places for other uses	-	No	Fill with geological materials	Fill using not hazardous materials	Fill with tailing, wastes and hazardous materials.
	Disturbed	Areas that, due to excavations for various purposes, in the shallow portions, suffered collapses.	-	No	-	Occur	Occur
	Landscaped	Areas that have undergone modifications for different uses and that it is not possible to fit into the previous categories	-	No	Golf course, sportive areas, airports	Occur	Occur
Hazard sources	Flooding	Evidence	-	No	No	Occur	Occur
	Creep	Evidence	-	No	No	Occur	Occur
	Landslides	Evidence	-	No	No	Occur	Occur
	Collapsible geological materials	Porosity, Texture, Dry unit weight	-	No	Occur <2 m deep	Occur with depth up to 5 m	Occur with depth up to 10 m
	Compressibility	Organic layers, Porous clayed layers	-	No	Occur <2 m	Occur in depth up to 5 m	Occur in depth up to 10 m
	Swelling	Clay minerals, Smectite percentage	-	No	Occur <2 m	Occur in depth up to 5 m	Occur in depth up to 10 m
	Dispersivity	Exchangeable Sodium Percentage, Electrical conductivity, Texture	-	No	Occur <2 m	Occur in depth up to 5 m	Occur in depth up to 10 m
	Soluble geological materials	Soluble minerals, Carbonates	-	No	No	Occur <1%	Occur
	Caves/Sinks	Evidence	-	No	No	Occur	Occur
Special aspects	Protection zones	Groundwater well	-	No	No	Occur	Occur
		Natural springs	-	No	No	Occur	Occur
		Lakes, Reservoirs	-	No	No	Occur	Occur

Table S3. Synthesis of suitability zoning for SuDSs.

	Basic characteristics					Suitability aspects				
Units	**Geological units (GU)**	**Hydraulic conductivity (K) of surface layer (cm/s)**	**Subunits**	**Groundwater level depth (m)**	**Rockhead depth (m)**	**Functional conditions**	**Constructive conditions**	**Subsurface drainage conditions**	**Potential subsurface water contamination conditions**	**Stability conditions**
1	GU 1 GU 2	10^{-3}–10^{-4}	1.1	>10	>10	Favorable/ Moderate	If the surface layer is compacted or absent due to anthropogenic activities, the construction conditions are restrictive.	If the surface layer is in natural condition, the behavior is favorable.	In some areas, there are possibilities for contaminants to reach the saturated zone, especially near the natural springs.	Collapsible materials
			1.2	>10	5–10	Favorable/ Moderate	Compacted or excavated surface layer due	Moderate conditions because the surface layer	Condition more severe than Subzone 1.1	Collapsible materials. When it over-

							to anthropogenic activities and the rock-head depth can limit the efficiency of the system.	is over layers with lower K values.		laps siltstones and claystones with expansive minerals from Fm Itaqueri, there may be expansion problems that affected the drainage system.
2	GU 3 GU 9	10^{-2}–10^{-4}	2.1	>10	>10	Favorable	Compacted or excavated surface layer due to anthropogenic activities and instability problem due to the low cohesion presented by the geological material can affect the construction.	Favorable, if the surface layer is not compacted or excavated. Runoff waters can present high sediment rates due to the high erodibility of geological materials.	The conditions are severe since it is a recharge area of the main regional aquifer, as well as the geological material presents low sorption capacity and retardation factor. It is advisable to use horizontal BRP according to the procedures set out in [40,41]	Collapsible geological material with high erodibility index which can generate instability in excavated slopes, as well as the generation of sediments.
			2.2	>10	5–10	Favorable	Similar to the subzone 2.1.	Similar to subzone 2.1.	Similar to the subzone 2.1.	Similar to the subzone 2.1.
			2.3	5–10	5–10	Moderate	Similar to the subzone 2.1.	Similar to subzone 2.1.	Condition more severe than in the subzone 2.1.	Similar to the subzone 2.1.
			2.4	5–10	>10	Moderate	Similar to the subzone 2.1.	Similar to subzone 2.1.	Condition more severe than in the subzone 2.1.	Similar to the subzone 2.1.
3	GU 1 GU 2 GU 11	10^{-3}–10^{-4}	3.1	5–10	>10	Moderate	The occurrence of compacted or excavated layers associated with the depths of the saturated zone imposes restrictions.	Moderate condition in the case of the layer with natural characteristics. If it is compacted or excavated, the restrictions are more significant.	The condition for potential contamination of the groundwater level near the natural springs is greater than in zone 1.	Collapsible materials. When it overlaps siltstones and claystones with expansive minerals from Fm Itaqueri, there may be expansion problems that affected

									the drainage system.
			3.2	5–10	5–10	Moderate	The depth and efficiency of the drainage system is affected by bedrock with very low hydraulic conductivity.	Moderate to severe due to shallow rockhead. Water accumulation may occur, generating a perched saturated zone and flow parallel to the rockhead surface.	Similar to Subunit 3.1.	Expandability issues can occur due to the presence of shallow siltstones and claystones.
			3.3	3–5	3–5	Moderate/ Severe	Similar to the Subunit 3.2.	Severe due to shallow rockhead. Water accumulation may occur, generating a perched saturated zone and flow parallel to the rockhead surface.	Similar to Subunit 3.1.	Similar to Subunit 3.2.
4	GU 4 GU 7 GU 8	10^{-3} to 10^{-7} (mainly $<10^{-4}$)		3 to 5	3–5	Severe	In unit 8 you can find boulders. In the saprolitic layers there is a possibility of expansive minerals.	Severe to restrictive due to hydraulic conductivity values and shallow groundwater level.	The geological materials have a high sorption and retardation capacity, which generates favorable protection for the groundwater.	Expansion may occur due to materials with expansive minerals as well as water accumulation generating the surface flow and the instability of the systems due to low permeability.
5	GU 4 GU 5 GU 6 GU 10 GU 7 GU 8	10^{-3}–10^{-7} (mainly$<10^{-4}$)		<3	<3	Restrictive	Restrictive	Severe to restrictive due to hydraulic conductivity values and shallow groundwater level.	Very shallow groundwater level	High compressibility and potential swelling associated with saprolites.