4. Locations where it is easier to flip a switch, rather than access a phone.
5. Locations where a near instantaneous control of illumination is critical in cases of emergencies.
6. Locations where it is not possible to access a phone.
7. Locations where any downtime of the server is a serious issue for illumination considerations (i.e., emergency-type environments).
8. A location where possible future switch control may be necessary. Similarly, a location where running wires while building is easy, but doing so after is much more difficult.

Some factors to consider in concern to illumination automation include:

1. Check for bulbs that can restore last state when power fails. Right now most bulbs will turn on after power failure. If a power failure happens when the user is out of town, they may return to their building to find the bulbs have been continuously on since the power failure. Herein, it is also possible to use motion sensors to remedy bulbs turning on after a power outage when the occupant(s) are not in the building.
2. Add a whole house battery backup or generator.

20 Architectural openings and circulation system

A.k.a., Building circulation, vertical circulation, horizontal circulation, etc.

Architectural circulation systems and the strategic placement of architectural openings are fundamental elements that profoundly influence the movement and flow within a built environment. Openings, such as doors and passageways, serve as conduits for spatial transition, allowing individuals to traverse and/or see through from one area to another seamlessly. In the realm of architectural design, buildings and their internal layouts can be classified based on the number and dimensions of unobstructed and obstructed openings within each room. By calculating the average number and types of doors or openings leading to each space or room, designers can optimize accessibility and functionality. Understanding the various ways to access different spaces or rooms within a habitat, sector, or building is crucial.

The common types of architectural openings are:

1. Wall openings (no obstruction to exterior).
2. Window openings (window obstruction, which may be capable of being opened to shift the glass obstruction out of the way).
3. Door openings (where, the door is an obstruction that can be opened to shift the door out of the way.

Openings create space for movement and flow. It is possible to classify buildings, and path layouts in general, by the number and size of unobstructed and obstructed openings any given room, building, sector, or habitat has:

1. Calculate the number (and type) of doors (opening) to each space and room.
    A. For example, a house has 6 rooms:
        1. Room 1: Living room has:
            i. 5 unobstructed openings.
        2. Room 2: Kitchen room has:
            i. 1 obstructed door.
            ii. 1 obstructed widow.
            iii. 2 unobstructed openings.
        3. Room 3: Bedroom room "A" has:
            i. 2 obstructed door (e.g., one into suite bathroom, and one into hallway).
            ii. 1 obstructed widow.
            iii. 0 unobstructed openings.
        4. Room 4: Bedroom room "B" has:
            i. 2 obstructed door.
            ii. 1 obstructed widow.
            iii. 0 unobstructed openings.
        5. Etc.

Rooms characterized by a higher number of openings often prioritize ventilation, natural light, and a seamless connection between spaces and people. This approach can be seen in warm climates where cross-ventilation is essential, or in cultures that emphasize large and strong family connections. Conversely, other cultures may opt for rooms with fewer openings, focusing on privacy, security, and climate control. These designs are prevalent in regions with extreme weather conditions, where minimizing heat gain or loss is critical, or in societies that prioritize enclosed, intimate spaces. The diversity in room layouts and the number of openings across cultures not only reflects functional needs but also cultural values and aesthetics.

A wide variety of spatial changes can be made to architecture that will affect the function and sensation of enclosed areas:

1. Nesting space (separating) .
2. Opening space (creating space; widening space).
3. Connecting spaces (flowing space; more openings for each space).
4. Clear space (uncluttered).

20.1 Architectural circulation

An architectural circulation system encompasses all the elements and features that facilitate movement and circulation within a building, enabling people and robots to navigate between different levels and areas efficiently and safely. Building circulation includes various architectural elements and systems that contribute to movement and accessibility. Some of the key circulation systems include, but may not be limited to:

1. **Staircases** - are a fundamental part of vertical circulation in buildings, providing means for people to move between different floors and levels. A staircase is a series of steps or flights of steps designed to provide a means of vertical movement between different levels or floors within a building or structure. Staircases play a fundamental role in architecture, facilitating safe and efficient circulation, allowing people to move between various levels with ease and under their own leg power. Staircases are typically constructed with a series of treads (horizontal steps) and risers (vertical portions between the treads), forming a continuous path for ascending or descending. The design and layout of a staircase can vary significantly, depending on factors such as the building's function, available space, aesthetic preferences, and accessibility requirements.
2. **Elevators (a.k.a., lifts)** - are mechanical systems that transport people and/or objects vertically between floors, ensuring accessibility for individuals with mobility challenges and allowing for efficient vertical movement. Elevators require electricity and hydraulic fluids, and must be maintained and monitored for continuous safe operation.
3. **Escalators (a.k.a., moving stairway, moving staircase)** - a moving mechanical device designed to transport people between different levels of a building in a vertical manner. Escalators consist of a continuous loop of steps or treads that move in a cycle, allowing individuals to step on and off the moving surface as it carries them smoothly and gradually between floors. Escalators require electricity and hydraulic fluids, and must be maintained and monitored for continuous safe operation.
4. **Moving walkways (a.k.a., travelator, horizontal escalator, horizontal circulator, moving conveyor)** - designed to transport people and/or objects horizontally or along a gentle incline. Unlike escalators, which move in a vertical direction, moving walkways are intended for horizontal movement. They consist of a moving surface or belt that moves in a continuous loop, allowing individuals to walk or stand on it while being carried along the path. Moving walkways enhance the ease of movement for passengers, making it more convenient to traverse extensive areas within a building or facility. Moving walkways require electricity and hydraulic fluids, and must be maintained and monitored for continuous safe operation.
5. **Ramps** - a sloping or inclined surface that provides an accessible means of movement between different levels or floors. Unlike staircases, which involve a series of steps, ramps offer a continuous and gradual incline, making them suitable for individuals with mobility challenges, strollers, wheelchairs, and other wheeled devices.
6. **Railings** - are protective barriers along staircases, balconies, and other elevated areas, ensuring safety and preventing accidental falls.
7. **Corridors and hallways** - are architectural elements connect various spaces within a floor or building, allowing for horizontal circulation and access to different areas.

21 Architecture communication sub-system

A.k.a., Communications, telecommunications, electrical signaling.

Communications systems convert electrical power into data-communications signals. These signals are sent, processed, transmitted, and received.

Architectural communication has several significant design elements:

1. Communication within the building.
   A. Support service systems.
   B. Automated control systems.
2. Communication outside the building.
   A. Local person-to-person communications.
   B. Internet communications.

The most significant characteristics of a communications system are:

1. Electrical power.
2. Electrical wiring.
3. Network switching.
4. Data transport.
5. Transmitting and receiving.

21.1 Communications standards

Just like other subsystem services (e.g., plumbing, electrical), there are communications standards, produced with different objectives.

21.1.1 Standard communications documentation

Communications systems are documented via specifications and drawings.

1. Communications drawings (a.k.a., communications schematics, light drawings) illustrate the system that will support illumination.
2. Communications specifications include all written content, reasoning for decisions, and calculations.

A communication drawing (communication system schematic) illustrates the communication system, including its wiring, powering, and distribution subsystem, and its qualities therein. Note that an electrical diagram may/will include a circuit diagram for communications.

There are two primary communications diagrams:

1. A wired communications circuit diagram - shows the powering, process, and wiring of a communications circuit(s) and the endpoints. In some cases, the main electric communications circuits are separate from the power ring main circuit.
2. An access distribution diagram - shows the location of communications endpoints (including outlets) and/or wireless network area of coverage.

21.1.1.1 Communications system plan

NOTE: *A communications plan may be a sub-section of the electrical plan.*

A communication plan necessarily involves:

1. Communication design diagram includes location wiring of sub-systems:
   A. Areas of wired coverage.
   B. Areas of wireless coverage.
   C. Electrical communications circuits.
   D. Electrical power wiring (e.g., ac/dc).
   E. Electrical communications wiring (e.g., ethernet).
   F. Communications computational processors (e.g., switches and routers).
   G. Architectural plug-in ports (e.g., RJ45 plug).

21.1.2 Standard communications requirements

What is required for a viable communications system is:

1. **For architecture** - Communications transmission proportionate to user demand.
2. **For economic calculation** - Data sheeting about demand (communications) to produce optimization calculation.
3. **For life support demand** - communications proportionate to human demand.
4. **For technology and exploratory demand** - communications proportionate to human demand.
5. **For transport** - communications proportionate to motion and safety.
6. **For walking** - communications proportionate to motion.
7. **For dwellings** - Appropriate communications systems for user-to-user and user-to-building communications.
8. **For working areas** - Appropriate communications infrastructure for safety, motion, and coordination.

21.1.3 Hazards with the illumination system

There are several hazards associated with an communication system, including but no necessarily limited to:

1. **Electrical hazards** - the communications system is powered by electricity, and thus, has the same

hazards as other electrically powered systems.

21.2 Objects in the communications system: fixtures, fittings, and appliances

Furniture fixtures and fittings are equipment that sit on or are otherwise attached to the architectural surfaces of a building for the specific purpose of resting objects:

1. **Communication fixtures** - furniture objects that are classified as fixtures are affixed to or through the architecture. The most common fixtures include, but may not be limited to:
   A. **Electrical power wiring.**
   B. **Electrical signals wiring.**
   C. **Graphical user interfaces.**
   D. **Data ports.**
2. **Communication fittings** - communications objects that are classified as fittings are not affixed to the architecture and are more immediately mobile. The most common fixtures include, but may not be limited to:
   A. **Routers.**
   B. **Switches.**
   C. **Graphical user interfaces.**

21.3 Installation of communications system

Communications objects are physically built and moved into place. Sometimes installation can be done by one or more people, and other times installation requires special mechanical and/or human assisted equipment.

21.4 Operation of communications system

Communications systems operate in a variety of ways, including:

1. Machine-to-machine.
2. Machine-to-human.
3. Human-to-machine.
4. Human-to-human.

Communications with and between humans requires a physical interface that the human sends and receives signals (data/information) through.

22 Architecture furnishings sub-system

A.k.a., Furniture, joinery, woodwork, millwork, casework, etc.

In architecture, the term "furnishings" can be used to encompass furniture, millwork, and casework. The category of "furnishings" refers to all the items, both movable and fixed, that are used to equip and decorate interior spaces. It includes furniture (movable items like chairs, tables, sofas), millwork (custom-made wooden architectural elements), and casework (pre-built cabinetry and storage units). These are three distinct categories of interior elements used in designing and furnishing spaces:

1. **Furniture** - refers to movable objects and pieces used to enhance the functionality and appearance of a space. These items are typically not fixed to the structure and can be easily repositioned or relocated. However, some furniture may be fixed to the floor, wall, or ceiling. Common examples of furniture include, but are not limited to: chairs, tables, sofas, beds, cabinets, and desks. Furniture serves various purposes, from providing seating and storage solutions to defining functional zones within a room.
2. **Millwork** - refers to custom-made wooden products and architectural elements produced in a mill or woodworking shop. These items are typically fabricated to fit specific spaces and are often built into the structure of the building. Millwork includes, but is not limited to: cabinetry, shelving, paneling, baseboards, crown moulding, wainscoting, cabinetry, built-in furniture, doors, and window sills. Millwork items are usually manufactured off-site and then installed on-site.
   A. **Casework** - is a subset of millwork that specifically refers to pre-built or pre-fabricated cabinetry and storage units. Unlike custom millwork, casework items are produced in standardized sizes and configurations, making them easier to order and install. Casework includes kitchen cabinets, bathroom vanities, wardrobes, and storage units with predetermined designs and dimensions.
3. **Decor** - refers to decoration (aesthetic presence only; may or may not have anything more than aesthetic function) added to architecture and architectural surfaces to enhance themes, moods, and feelings. For instance, fabrics, carpets, wallpaper/paint designs, trim and moldings, glass color, texture, mullion design, window reveal detail, etc. Furniture and millwork details can be

considered decor.

22.1 *Furniture standards*

Just like other subsystem services (e.g., plumbing, electrical, etc.), there are standards for furniture.

22.1.1 Standard furniture documentation

Furniture systems are documented via specifications and drawings.

1. Furniture drawings (a.k.a., surface schematics, surface drawings) illustrate the system that will support illumination.
2. Furniture specifications include all written content, reasoning for decisions, and calculations.

Furniture may have the following diagrams:

1. Object construction diagram.
2. Object usage diagram.
3. Object placement diagram.
4. Object maintenance diagram.

22.1.2 Standard furniture requirements

What is required for a viable furniture system is:

1. **For architecture** - Furniture appropriate for:
   A. Aesthetics.
   B. Function.
2. **For walking and transportation** - Surfaces designed proportionate to motion and surface composition, including the maintenance (cleaning) of the surface.
   A. **For transport** - Furniture proportionate to motion and safety.
   B. **For walking** - Furniture proportionate to disability.
3. **For economic calculation** - Data sheet about furniture composition, usage, and safety to produce optimization calculation.
4. **For life support demand** - Furniture proportionate to human demand.
5. **For technology and exploratory demand** - Furniture proportionate to human demand.
6. **For dwellings** - Furniture proportionate to human demand.
7. **For working areas** - Furniture proportionate to human and production demand.

22.1.2.1 Standard furniture efficiencies

Furniture can be made more efficient by reducing:

1. The amount of materials used.
2. The labor associated with production
3. The labor associated with installation.
4. The necessity to maintain/clean the furniture.

22.1.3 Furniture and function

All furniture is designed to meet a function. Two of the most important considerations to get correct when making furniture is:

1. The height of the furniture.
2. The material composition of the furniture (e.g., is the material composition appropriate for wet or dry spaces).

22.1.4 Hazards with the furniture system

Common hazards with the furniture system include, but may not be limited to:

1. Off-gassing (a.k.a., out-gassing) of harmful chemicals.
2. Falling over (for tall furniture; including, dropping).
3. Cleaning issues.
4. Sharpness of edges.
5. Pinching (for furniture that moves).

22.2 *Objects in the furniture system: fixtures, fittings, and appliances*

Furniture fixtures and fittings are equipment that sit on or are otherwise attached to the architectural surfaces of a building for the specific purpose of resting objects:

1. **Furniture fixtures** - furniture objects that are classified as fixtures are affixed to the ground and not immediately mobile without unattaching. The most common fixtures include, but may not be limited to:
   A. **Storage furniture:** These are areas that hold or otherwise store objects. Some of these fixtures store objects inside of themselves (e.g., cabinet), and some store objects on top of themselves (e.g., table).
      1. **Shelving (architecturally attached)** - are individualized planks (generally, horizontal) that store objects.
      2. **Cabinets (with and without shelving)** - are objects that store objects within themselves.
         i. Permanently open cabinets - cabinets with no doors).
            1. Cabinets with connected appliances inside (e.g., oven or dishwasher inside a cabinet space).
            2. Cabinets without connected appliances.
         ii. Open-close cabinets - cabinets with doors. The doors to a cabinet can be mesh and some degree of opaque to transparent

(glass).

3. **Tables (architecturally attached)** - are objects that store other objects on top of themselves for direct access and/or observation via humans. Tables can have shelving within them (i.e., table with shelves). When a table allows for storage inside (i.e., table with cabinet).

B. **Sitting and lying furniture:** These are objects that allow humans to sit or be in a non-upright form.
   1. **Chairs (architecturally attached).**
      i. One person chair.
      ii. Multi-person chair.
   2. **Lying furniture (i.e., sleeping furniture, beds):** These are objects that allow humans to lie down and are attached to the architecture. Wall folding beds are an example of architecturally attached lying furniture.

2. **Furniture fittings** - furniture objects that are classified as fittings are not affixed to the ground and are more immediately mobile. The most common fixtures include, but may not be limited to:
   A. **Object storage furniture:** These are objects that store other objects.
      1. **Shelving (freestanding).**
         i. With and/or without wheels.
      2. **Cabinets (freestanding).**
         i. With and/or without wheels.
      3. **Tables (freestanding).**
         i. With and/or without wheels.
      4. **Boxes (or cans)** can be used to store objects and/or waste.

3. **Furniture appliances** - appliances and objects that change the surface, the most common of which include:
   A. **Connectors** - mechanical devices (sometimes magnetic) that connect furniture to furniture and furniture to architecture. An example of a connecting device is a cabinet door hinge.
      1. **Mechanisms** - mechanical (and sometimes, magnetic) systems that connect objects in a dynamic way.
      2. **Hooks** - mechanical (and sometimes magnetic) objects that statically connect (Read: hook) mobile objects to architecture or other freestanding objects.
   B. **Locks** - mechanical (and sometimes magnetic) devices that lock objects to other objects.

22.3 Installation of furniture system

Furniture objects are typically physically built separately from the building and moved into place in and or around a building. Sometimes installation can be done by one or more people, and other times installation requires special mechanical and/or human assisted lifting equipment (e.g., crane in the mechanical sense, and lift ropes in the case of human assisted).

However, in total, there are several ways to integrate furniture (technologies) into an area/room:

1. **Integration of furniture into the structure** (a.k.a., furniture-based). In other words, the furniture becomes part of the structural enclosure of the building itself (i.e., structurally fixed). For example, shelving that is part of and extends out from the original wall itself. This is a furniture-centric arrangement; the furniture was so central to the room that it was built-into the structure of the room.
2. **Attachment of the furniture to the structure.** The structure non-load bearing removable fitting; somehow attached, but also relatively easy to remove. For example, shelving easily removed from small wall-shelf connectors. Or, attaching seats to a floor in an airport or stadium.
3. **The furniture is not fixed to any surface** significantly, (except via gravity to the floor). These types of rooms/homes are often called "space-based" systems. For example, a standing bureau with selves. The furniture can be changed and moved with relative ease. There is more flexibility here with space usage, than when furniture is attached to a structure affixed to a surface.

Of significant note here about the in-fixing of infrastructural services is that some homes are:

1. "Space-based" systems - meaning that the furniture can change place because on an unobstructed room.
2. "Furniture-based"; there was no fixed furniture in the rooms, so the residents could easily change the function of rooms as needed. It is important to mention that this strategy arose from the simple traditional lifestyle before the modern period.

22.4 Operation of furniture system

In general, furniture systems require little specialized operation. Doors (drawers, etc.) are opened and closed by either humans or automated mechanisms. Most furniture is operated in the sense that elements of it are opened and closed, as needed, by the user(s).

22.4.1 Furniture load demands

A.k.a., Furniture loading.

Furniture loads are measured primarily in the following ways:

1. Gravity:
   A. Weight (and mass) capacity as amount of weight a furniture object can sustain and remain a viable structure (and not, break).
   B. Stability: Likelihood of overturning (or, becoming unstable) given accidental pressure.
2. Resistance to damage and failure from:
   A. The elements and contact with other [accounted for] materials.
   B. Repeated cleaning.
3. Electricity (electrical power) to do the work of motion in dynamic furniture systems.

22.5 Common furniture materials

Most furniture is made out of some combination of wood, fabric, metal, plastics, adhesives, or glass. Some furniture also has stone as part of its composition.

23 Architecture thermal sub-system

A.k.a., Thermal control engineering, thermal energy design optimization.

It is essential to consider energy saving techniques and materials when designing buildings. Consideration is given to the placement of windows, doors, and even to where a structure is located on a property. Buildings and their subsystems can be designed and integrated to better account for and use thermal energy. Whole-building energy simulations can optimize the thermal design of a building. Thermal energy design is necessary for both:

1. Energy sustainability (a.k.a., energy savings).
2. Human comfort.

Human thermal comfort has been defined as the condition of the psycho-physiology that expresses satisfaction with the surrounding environmental temperature.

The are factors that affect thermal sensation include, but may not be limited to:

1. Air temperature.
2. Humidity.
3. Air velocity.
4. Mean radiant temperature.
5. Clothing levels.
6. Human metabolic rate.

Thermal characteristics in architecture can be categorized as either passive (requiring no continuous energy use) or active (relying on continuous energy consumption, which is less sustainable). Temperature and ventilation control within a building can fall into either of these categories. For instance,

1. Opening windows on a hot day to encourage natural airflow is considered a passive approach.
2. Activating a heater on a cold day is an example of an active method.
3. Designing a building with the correct orientation to harness sunlight for natural warming in winter and cooling in summer exemplifies a passive technique that maximizes sustainability.

23.1 Energy conservation standards

Thermal energy standards include the construction, installation and use of boilers, chimneys, flues, hearths and fuel storage installations. The primary standard for architectural energy conservation is:

- The International Energy Conservation Code from

The International Code Council [iccsafe.org].

23.2 Thermal optimization factors

In concern to the architectural thermal sub-system, it is important to account for the thermals inside an architectural object and also to account for the thermals between buildings in the built environment:

1. **Intra-building thermals (within architectural objects):** This aspect focuses on controlling and optimizing the thermal environment inside buildings to ensure comfort, energy efficiency, and sustainability. Key considerations include:
   A. **Insulation:** High-quality insulation helps reduce heat transfer between the building's interior and the external environment, maintaining comfortable indoor temperatures and reducing heating and cooling demands.
   B. **Pressurization:** Pressurization within buildings plays a critical role in thermal management and overall environmental control. Positive pressurization (more commonly just called "pressurization") is used to prevent uncontrolled infiltration of outside air, which can carry heat, humidity, and pollutants into the building. De-pressurization, on the other hand, can occur in certain areas of a building due to factors like exhaust systems, potentially leading to unwanted drafts and energy inefficiency.
   C. **Thermal mass:** Materials with high thermal mass can absorb and store heat energy, which helps stabilize indoor temperatures by reducing fluctuations over time.
   D. **Ventilation:** Effective ventilation systems can remove excess heat and humidity from indoor spaces, improving air quality and thermal comfort.
   E. **Windows and glazing:** The selection of windows and glazing materials plays a significant role in controlling heat gain and loss through fenestration. Techniques such as double glazing and the use of low-emissivity coatings can enhance thermal performance.
   F. **HVAC systems:** Efficient heating, ventilation, and air conditioning systems are essential for regulating indoor temperatures and ensuring thermal comfort.
2. **Inter-building thermals (between buildings in the built environment):** This aspect addresses the thermal interactions between buildings within an urban or community setting. It includes the consideration of:
   A. **Urban heat island effect:** The concentration of buildings and infrastructure can lead to higher temperatures in urban areas compared to surrounding rural areas. Mitigation strategies include the use of reflective materials, green roofs, and increased vegetation.
   B. **Solar reflection and absorption:** The orientation and external surface materials of buildings can affect solar heat absorption and reflection, impacting not only the building itself but also neighboring structures.
   C. **Wind flow:** The arrangement of buildings influences wind flow patterns, which can affect natural ventilation and cooling strategies for surrounding buildings.
   D. **Shading:** Strategic placement of buildings and landscaping can provide shading, reducing solar heat gain and cooling loads for neighboring buildings.
   E. **Thermal buffer zones:** Creating spaces between buildings, such as courtyards or green areas, can serve as thermal buffer zones, helping to regulate microclimates and reduce heat transfer between buildings.
3. **Integrating intra- and inter-building thermal control:** Effective thermal control in architecture requires an integrated approach that considers both intra- and inter-building dynamics. This involves:
   A. **Holistic design strategies:** Designing with a comprehensive view of the built environment, considering the individual performance of buildings as well as their collective impact on urban thermals.
   B. **Simulation and modeling:** utilizing advanced simulation tools to predict thermal performance and optimize design choices for both individual buildings and urban layouts.
   C. **Sustainable materials and technologies:** Incorporating materials and technologies that enhance thermal performance and sustainability, such as phase change materials, solar control films, and adaptive facade systems.
   D. **Collaboration across disciplines:** Engaging architects, urban planners, environmental engineers, and other professionals in collaborative efforts to address thermal challenges in the built environment.

Thermal considerations for the design of structures include:

1. Building architecture specific factors:
   A. Shading.
   B. Openings.
   C. Ventilation.

    D. Materials and surface finishes.
2. Site specific factors:
    A. Location on planet.
    B. Location on site.
    C. Shading on site.
    D. Direction on site.

NOTE: *These energy factors are all interrelated. Any mention of one factor will necessary include a mentioning of the other(s).*

The three primary thermal considerations are:

1. Sunlight.
2. Exterior environmental temperature.
3. Interior temperature changes (e.g., heaters).

Sunlight is electromagnetic radiation that will pass through glass windows to varying degrees due to composition, and can make a building (its interior and exterior) hot.

23.2.1 Passive solar optimization

One of the most important energy efficiency factors in any building is its orientation. How a building is oriented in relation to the sun can have a dramatic impact on heating and cooling – the largest energy contributor in most homes.

1. Passive solar gain:
    A. Gain of temperature: The sun can heat surfaces during the day that provide warmth during colder (darker) hours. Through strategically placed openings in buildings it is possible for the sun to reach, warm, and light areas where it otherwise would not. Surfaces facing sunlight can collect, store, and release heat.
    B. Gain of natural sunlight: Natural sunlight is generally preferable inside during daytime.
2. Unwanted passive solar heat transfer: The sun can heat surfaces that transfer the thermal energy into undesired locations (e.g., a metal thermal bridge that is visible to the sun outside and open to the atmosphere inside. The sun can make it more difficult to maintain a desired indoor temperature.

The general principles for orientation and design of a passive solar house are:

1. Location:
    A. In the northern hemisphere have windows (openings) facing the equator (south).
    B. In the southern hemisphere have windows (openings) facing the equator (north).
    C. At the equator:
        1. Insulate roof well, and possibly have ventilation.
        2. Keep the sun away from the thermal mass in order to keep it cool.
        3. Have the ability to shade windows.
2. Thermal shading surfaces:
    A. Shade from hot summer heat.
3. Thermal storage surfaces:
    A. Walls and stone-type floors act well as thermal collectors.
4. Insulation:
    A. Insulate windows appropriately.
    B. Insulate structure appropriately.
5. Glass (transfer)*:
    A. Vertical windows - Vertical windows capture winter heat and reflect heat in summer.
    B. Angled windows - Angled windows collect heat best during winter months (with a low sun). Increases the amount of solar energy that can be stored.
    C. Horizontal windows (skylights) - Skylights collect heat best during winter months. Increases the amount of solar energy that can be stored. Can cause overheating in summer.

** Note: Glass may often have "stickers" (or other deflectors) attached to it where birds are present to prevent bird strikes.*

Many passive solar buildings build airflow into the house, such that changes in temperature cause changes in air movement. Sometimes this type of building is referred to as an “envelope house”. A lot of passive solar builds also incorporate clerestory windows that open and close near the top of the house. Because warm air rises, the clerestory windows allow the heat to easily escape out of the house, and can be closed when the house reaches a temperature that the occupants determine.

23.2.1.1 Sun path to object orientation software

There are a number of software solutions available that allow for visualization of buildings in relation to the path of the sun throughout the year.

- Sun-Path 3D-Web [andrewmarsh.com/software/sunpath3d-web]
- Epic Unreal Engine [unrealengine.com]
- SketchUp w/ Curic Sun [sketchup.com] [extensions.sketchup.com]
- Solar survey data resource center (Build It Solar) [builditsolar.com]

23.2.2 Shading (in the context of thermal energy) Optimization

Shading can be used to reduce the amount of transmitted radiation into a closed space. Traditional shading devices have included overhangs, venetian blinds, and trees or bushes. Shading is very beneficial during seasons of overheating due largely to the positioning of the sun. Determining the exact periods of overheating in an area is obviously important to builders. Decisions on where and when to include shading can greatly affect the comfort level inside a closed space.

23.2.3 The heat island effect

The "heat island" effect refers to the elevated temperatures experienced in urban areas due to the excessive retention of heat on a landscape covered with solid architectural surfaces. Of note, permeable pavers can mitigate this effect to some relative degree by allowing heat dissipation through evaporation, reducing surface temperatures. Using light-coloured permeable materials further aids in reflecting sunlight instead of absorbing it.

23.2.4 Thermal bridging

A thermal bridge is a localised area of the building envelope where the heat flow is different (usually increased) in comparison with adjacent areas (if there is a difference in temperature between the inside and the outside). In other words, a thermal bridge results when the inside and the outside of the building are directly connected through elements that are more thermally conductive than the surrounding areas of the structure (e.g., screws penetrating, beams penetrating, joists passing through an insulation layer). Thermal bridging is a major cause of poor energy performance, durability, and indoor air quality of buildings. Thermal bridging results in condensation, and a high (or, higher) potential for mold. One of the most regular locations of thermal bridging is at window framing points.

To prevent thermal bridging, the following options are available for window installation:

1. Glass glazing (glass panes): Use double, triple, or quad glazing.
   A. Gas glazing (gas filled panes): Gas filled glazing. Argon gas is cost effective and provides a good boost in performance over air-filled units. Krypton gas, while more costly, provides an increase to performance.
   B. Frames: Select frames made of low conductive materials. Aluminum frames without thermal breaks are a complete no-no for energy efficiency and comfort. Aluminum is a high conductor of heat. Note, thermally broken aluminum is a good option depending on how good the thermal break is.
   C. Spacers: Spacers are the material attached to the surface structure of the windows between each glazed window pane. Selecting windows with better spacers can help prevent thermal bridging in the windows as well. These spacers separate the panes of glass and appear where there are divided lights. Avoiding spacers made of aluminum and steel, and selecting stainless steel and various composite materials are much better options.
   D. Installation: Proper window installation including air sealing and insulation around the windows will significantly reduce the amount of energy loss.

23.2.5 Combustion heating and exterior atmospheric intake

When combustion heaters are operating, they create a vacuum effect that will pull air into the house from outside. In the case of a tightly sealed or airtight home, this process may even draw air in through pipes or other unintended openings. One effective solution is to install an incoming air vent near the combustion heater or to pipe exterior atmosphere directly into the combustion system itself. This ensures a controlled and direct source of fresh outdoor air for combustion, reducing the risk of negative pressure within the home and improving the overall efficiency and safety of the heating system. By implementing these measures, homeowners can strike a balance between maintaining airtightness and ensuring adequate ventilation, creating a healthier and more energy-efficient indoor environment.

Any source of combustion, whether it's a combustion heater, fireplace, or stove, relies on a continuous supply of fresh air for the combustion process. When these devices are in operation, they naturally draw in fresh air from their surroundings to support the combustion of fuel. This essential airflow not only sustains the combustion process but also prevents the buildup of harmful byproducts like carbon monoxide within the living space. Therefore, proper ventilation and a controlled source of outdoor air are critical considerations when incorporating combustion-based heating systems into a home, ensuring both safety and efficiency in the combustion process.

23.2.6 Openings and ventilation (in the context of thermal energy) optimization

Openings in the building provide ventilation. Ventilation is the intentional introduction of outside air into a building to ensure the health and well-being of the occupants that inhabit it (Hill). The function of ventilation can be arranged in three categories:

1. Health comfort ventilation.
2. Thermal comfort ventilation.
3. Structural ventilation.

Health comfort ventilation helps ensure the quality of indoor air by replacing it with outdoor air. Thermal comfort ventilation prevents bodily discomfort by removing excess skin moisture that ordinarily would decrease the dissipation of heat. Health ventilation replenishes oxygen supplies and prevents the toxic build up of carbon monoxide.

In general, windows are considered separately from regular walls, because they behave like holes in the wall. Windows (Read: windowed openings) can quickly affect the overall comfort level of the structure. Glass windows or openings transfer heat by either conduction or direct transmission.

23.2.6.1 Glass windows

Like all materials the ability of glass to conduct heat is measured by its insulation value. Even though insulated glass will reduce heat flow considerably, the heat transfer rate through glass is still several times greater than through a well-insulated wall. Regardless of glass' poor resistance to heat flow, solar radiation can be transmitted through it instantly. This gives glass areas a much greater influence on the heating and cooling potential within a building. When solar radiation strikes a window some of it will be reflected, some of it will be absorbed and some will be transmitted. The proportion of solar radiation that will be absorbed, reflected, or transmitted depends on the angle of the sun's rays that strike the glass. For instance, when the sun strikes the glass in a perpendicular direction, the transmitted component is large and the reflected component is small. At incidence angles greater than 60 degrees, the reflected proportion increases, and the transmitted proportion or component decreases. It is the transmitted component that influences the thermal conditions of space inside a structure.

23.2.7 Materials (in the context of thermal energy) optimization

Certain materials are more likely to decrease heat transmission, and other materials are more likely to increase heat transmission.

The thermal behavior of a material is a function of its:

1. Density.
2. Thermal conductivity.
3. Specific heat capacity.

'Thermal mass' is an attribute that represents the best combination of these three properties of a material for:

1. Absorbing (energy acquisition).
2. Storing.
3. Slowly releasing heat (energy transfer).

Materials with thermal mass readily absorb excess heat without getting hot. This heat may be from the sun or from internal loads, such as lights and computers. Once ambient temperatures drop, the thermal mass will slowly release stored heat to the surrounding environment without getting cold. Optimal use of thermal mass can reduce a building's energy use, environmental footprint and peak-energy loads, as well as increase occupant thermal comfort.

Suitable building materials for thermal mass are those that have high specific heat, high density and low conductivity. Insulation materials, such as fiberglass and polystyrene foam, have low conductivity, but their density and specific heat are too low to provide thermal mass. Metals have high specific heat and density, but their levels of conductivity are too high. Materials like brick, stone, adobe and concrete have suitable properties for thermal mass.

23.2.7.1 Fluid-based thermal energy acquisition, storage and transfer systems

It is possible to include a fluid-based heat exchange circuit embedded in the structure of a building (Uribe, 2015).

It is possible to design a building that includes:

1. A fluid heat exchange circuit (in structure of building) that transfers heat between:
   A. A solar collector (located in the roof).
   B. A low enthalpy geothermal heat store (ground heat exchanger).
   C. A dynamic thermal barrier (walls).

These sub-systems can be interconnected by the hydraulic circuit that controls the fluid flow.

23.3 Insulation optimization factors

A.k.a., Insulation engineering.

Today insulation is one of the most efficient ways in which builders can protect the inside space of structures against fluctuations in outside temperatures. Thermal insulators are those materials that restrict the flow of heat.

Thermal insulation materials have a low thermal conductivity which serves to limit the flow of heat energy between one side of the insulation and the other. In the build environment thermal insulation is typically used to reduce the passage of heat between the inside of a building and the outside.

In architectural science, heat is transferred through:

1. **Radiation** - heat transfer mechanism because heat energy is transmitted as electromagnetic waves.
2. **Convection** - heat moves through liquid or gas molecule mediums.
3. **Conduction** - heat energy is transferred between bodies in direct contact.

4. **Evaporation** - heat in this mechanism is transferred through water vapor where by heat is lost to the atmosphere through vapor.

Insulation provides for a passive restriction of heat by either of the above-mentioned methods. Insulators act as sieves, holding back some of the heat but not completely blocking all of it. The amount of heat that would pass through a material depends on the type of material. The ability of any material conduct heat is measured by its insulation value.

The insulation values used to evaluate the amount of heat flow/transferred through a material are:

1. **U-value** - represents the amount of heat that flows through a square foot of material in one hour.
2. **k-value** - the conductivity value of a material. It reflects the amount of heat that can pass through one inch of thickness of a material.
3. **R-value** - the number of square feet it takes for one BTU to pass through a material. BTU is the amount of heat it takes to raise the temperature of one pound of water one degree Fahrenheit.

Insulation is the basic feature in a building's structure necessary to protect it from the changes in outside temperature. If properly designed, insulation can greatly increase the comfort level within a structure. Thermal insulators are those materials, which block or decrease the flow of heat. These insulation materials can drastically decrease the flow of heat through all three modes of transfer: radiation, convection and conduction. Insulation serves three purposes as it relates to the three modes of heat transfer. First, insulation may act as a reflection material that reflects electromagnetic waves of radiation. Secondly, it acts to trap air and other gases preventing these gases from transferring heat through convection. Thirdly, it acts to sieve out heat by providing a material that has a high resistance to heat transfer through conduction.

All insulation is rated according to its “U” or “R” value, but it is also classified according to its physical characteristics. These classifications are largely determined by the physical properties of the materials that make them up. Some of the physical characteristics of insulation include low or high densities, high or low compressibility, stiff or loose consistency, frothiness, and reflective ability.

The word ‘insulate’ means to protect something by interposing a material between it and other elements that prevents transmission between them. The word ‘insulation’ refers to the material that is interposed. Insulation may be used in the construction industry for a number of different purposes:

1. **Thermal insulation** - to prevent the transmission of heat, typically between the inside and outside of a building. For more information see: Thermal insulation.
2. **Acoustic insulation (sound insulation, acoustic control)** - to prevent the transmission of sound, for example between a recording studio and a performance space. Sound insulation describes the reduction in sound across a partition. **Privacy** describes the perceived sound reduction across a wall. Privacy is a function of both sound insulation and background noise. **Background noise** is made up of services noise and environmental noise sources breaking in through the facade or open windows, vents etc. Two parameters are used to describe the sound insulation of a partition are:
   - **Dw** - represents the sound insulation between rooms on-site. Dw levels are specified by clients and Building Regulations.
   - **Rw** - represents the lab tested sound insulation of an element making up a partition wall/floor type.
3. **Fire insulation** - to prevent the passage of fire between spaces or components. Fire insulation (or more usually fire-rated or fire-resistant insulation) is a term that covers insulation materials which have insulative properties but are also non-combustible or have limited combustibility. Fire insulation is a passive fire protection element. It does not need to be activated to provide fire resistance, and hence, can help prevent the spread of flame between spaces and components within and between buildings.
4. **Electrical insulation** - to contain and separate electrical conductors and to limit the spread of electromagnetic fields.
5. **Insect insulation** - to keep out and prevent the passage of insects.

There are many different types of insulation, which vary in terms of colour, surface finish texture, core composition and performance. Very broadly however, they tend to be open cell or closed cell.

1. **Open cell insulation** - allows the passage of air through air pockets, but the route is so complex that effectively, no air will pass from one side to the other, and so heat transfer by convection is prevented.
2. **Closed cell insulation** - formed by bubbles of gas whose thermal conductivity is very low.

Common types of insulation include, but are not limited to:

1. **Blanket insulation (also called matting insulation)**.
   A. **Mineral wool** - refers to fibre materials that are formed by spinning or drawing molten minerals. It can be manufactured in various thicknesses

24 Automation design optimization

A.k.a., Automation engineering, automation control engineering, building automation systems, home automation systems, etc.

Building control functions can be automated using automatic control, regulation, and monitoring of building functions. It is possible to integrate all building functions integrated into one automation system. It is possible to develop and operate building wide control (automation) systems, commonly known as building automation systems (BAS). In many buildings around the world, particularly newly built buildings, physical switches are being replaced by digital wireless controllers. These controllers (Read: automation or smart building technologies) can be used to control and automate:

1. The entire electrical connection system of a building.
2. Illumination.
3. HVAC.
4. Audio and video systems (AV).
5. Plumbing.
6. Curtains and blinds.
7. Doors and windows.
8. Access Control (security).
9. Pools and water features.
10. IT peripherals.

There are currently solutions that cover all aspects of building automation, including but not limited to:

1. **Intelligent lighting control** - needs based lighting control. Numerous conventional switching devices are no longer required, the optimized switching activation and deactivation of loads reduces energy consumption, and the high flexibility of the control system permits later changes with little user effort.
2. **Control of room/area parameters** - needs based area control
3. **Swimming pool and water features control** - automation of pools and ponds. These systems can monitor and adjust:
   A. The water level (Read: water quantity).
   B. The water quality.
   C. The water temperature.
   D. Other water parameters.
4. **Water pump control** - automation of water pumps. These systems may be capable of controlling at least:
   A. Irrigation.
   B. Fountains,
   C. Cisterns
   D. Lifting and pressure pumps.
   E. Etc.
5. **Doors, gates, windows and other openings** - needs based accessway controls.
6. **Access control** - needs based access control. Some access control involves the control of doors, gates, and windows.
7. **Safety and security/alarming control** - needs based safety and security automation.

Problems with smartphone and tablet based automation systems include, but may not be limited to:

1. The app continues to still exists and is supported.
2. The app is installed on the occupants smartphone/tablet.
3. The device has a charged battery. For instance, the phone is asleep or the battery is dead and someone needs to turn on a light at 02:00.
4. The device is missing. For instance someone misplaced or broke their phone.
5. The device is properly paired with the building's network.
6. The device and app respond quickly.
7. Potential for increased wireless radiation.
8. May not be dependable in emergency situations.

A reasonably complete automation system for a dwelling-type structure may include the following:

1. Functions:
   A. What functions must the system perform?
   B. what sub-systems must the controller control?
2. Wireless solution - radio frequency solutions including wifi and bluetooth.
3. Wired solution - ethernet wired solutions.

The means of control include:

1. Mobile app[lication].
2. Computer application.
3. Voice.
4. Automatic (programmed).

24.1 Control sub-systems

An architectural control system generally comprises the following sub-systems:

1. A human-machine interface (HMI).
2. Programmatic control logic.
3. Computational processing hardware.
4. Timing and sequencing hardware (e.g., swtiches).
5. Communication interfaces (e.g., wifi router) serving as the head end of a point-to-multipoint network.
6. Individual client devices.

and widths and is often supplied in rolls.
   B. **Sheep's wool** - real wool from sheep that is often treated to make it more fire and insect resistant.
   C. **Glass wool (fiberglass or glass fiber)** - consists of glass fibres arranged using a binder into a wool-like texture.
2. **Foam boards** - rigid panels of insulation which are cut and fitted in place. Most commonly they are made from polystyrene, polyisocyanurate, and polyurethane
3. **Radiant barriers** - consist of a highly reflective material that reflects radiant heat rather than absorbing it.
4. **Blown-in insulation** - typically involves mineral fibres being blown into a void in the space that needs insulating.
5. **Spray foam insulation** - typically formed of polyurethane and is sprayed as a liquid which gradually expands to up to 100 times its original volume. Once set, it creates an effective thermal and noise insulating layer. Slow-curing foams can be used for cavity walls as they will flow around any obstructions before hardening. As spray foam can produce dangerous fumes and damage the structural integrity of the building if applied incorrectly
6. **Structural insulated panels (SIPs)** - a form of composite sandwich panel system that take the form of an insulating core (such as closed-cell polyurethane foam or expanded polystyrene) sandwiched between two structural facings.
7. **Aerogel insulation** - a lightweight solid derived from gel in which the liquid component of the gel has been replaced with gas. Areogel insulation comes in sheets of wrapping that are placed in a surface of the structure as insulation.
8. **Transparent insulation (versus opaque insulation)** - materials that perform a similar function to opaque insulation, but they have the ability to transmit daylight and solar energy, reducing the need for artificial light and heating. There are four common types depending on the structure of the material:
   A. Absorber perpendicular.
   B. Absorber parallel.
   C. Cavity.
   D. Quasi-homogeneous.
9. Other types of insulation.

In an architectural construction, insulation is most commonly applied to:

1. Floors (floor insulation)
2. Walls (wall cavity insulation)
3. Roofs (roof insulation)

The insulation thermal quantities can be calculated using:

1. **R-value (r-factor)** - the capacity of an insulating material to resist heat flow. The higher the R-value, the greater the insulating power.
2. **U-value (a.k.a., thermal transmittance)** - the rate of transfer of heat through a structure.

This can be a single material or a composite and the graphic below shows the relationship of U-value to R-value.

The U-value of a wall (or window) is the inverse of the sum of the R-values of that wall's (or window's) components (i.e., a low U-value is preferable). The higher the U-value, the faster heat flows through the material. The lower the U-value, the slower the heat flows through the material.

The formula is:

$$U = 1 / (R1 + R2 + R3)$$

$$U = (1 / R) = (QA / \Delta T)$$

Wherein,

- QA = Heat transfer rate
- ΔT = Temperature difference (inside versus outside)

23.3.1 Recreational insulation design

Some recreational facilities (exploratory service sub-systems) will produce a relatively large amount of noise and/or light pollution. These environments, when commonly accessed, need to have a sufficient insulation, either structurally, or in land area between. For example, the important consideration for a pool's placement for common access is a position (generally) that is highly sound isolated from residences, if children will frequent them. The requirement to remember about common children-accessible pools, is that they may scream loudly. This is similarly the case with sports stadiums. Insulation can come in the form of:

1. Localized structural [attenuation], and/or
2. Spatial land area and 3D objects attenuation.

In other words, requirements for optimizing insulation must account for master habitat service system strategic planning at both object and distance (object-to-object) levels.

24.2 Common automatable systems

The following are the most commonly desired and automatable systems associated with architecture:

1. Water automation:
   A. Pool automation.
      1. Pump automation (time-based).
      2. Chemical introduction automation (sensor-based or time-based).
      3. Liquid volume automation (sensor-based).
         i. Overfill/flow automation.
         ii. Filling automation.
   B. Bath automation:
      1. The water with correctly set temperature will fill up the bath and turn off when full. This can be accomplished via a smart phone.
2. Illumination automation:
   A. Electrical lighting
      1. Presence sensor.
         i. Bathroom (or other room).
         ii. Outdoor stairs.
         iii. Indoor stairs.
      2. All lights can be turned on and off via smartphone.
      3. Programming of certain lights to turn on and off at certain times of day (indoor and outdoor lights).
   B. Electrical shades/blinds.
      1. Can be opened and closed via a smartphone.
      2. Can be programmed to open and close at certain times of day.
   C. Window automation.
      1. Can be opened and closed via a smartphone.
      2. Can be programmed to open and close at certain times of day.
3. HVAC automation (climate control; temperature, and humidity control):
   A. Program.
      1. Heat pumps (or other HVAC system) can be turned on and off with a smart phone.
      2. Programming of heat pumps (or other HVAC system) to turn on and off at certain times.
4. Other machine automation:
   A. Garage door:
      1. Can be opened and closed via a smart phone.
   B. Sauna
      1. Can be turned on and off via a smart phone.
   C. Etc.
5. Cleaning:
   A. Floor-based robot vacuum cleaner.
   B. Window-based robot washing cleaner.

24.3 Building automation software

Common automation software includes, but is not limited to:

1. Node-RED: an open source programming tool for wiring together hardware devices, APIs and online services in new and interesting ways. It provides a browser-based editor that makes it easy to wire together flows using the wide range of nodes in the palette.
2. Home Assistant: Open source home automation that puts local control and privacy first. Powered by a worldwide community of tinkerers and DIY enthusiasts. Perfect to run on a Raspberry Pi or a local server.

25 Accessway design optimization

A.k.a., Site access, building access, and accessibility engineering.

An accessway is a path, route, opening, etc., that provides access to a specific destination or area.

There are two types of accessway:

1. Unobstructed accessway - open pathway/driveway.
2. Obstructed accessway - inclusive of a door or gate.

Buildings should be accessible to, functional for, and safe for use by their users, who may include:

1. Humans:
   A. Normal functioning humans (a.k.a., nominal accessibility).
   B. Humans with disabilities (a.k.a., disability accessibility).
2. Animals (animal accessibility).
3. Vehicles (vehicle accessibility).
   A. Human driven.
   B. Automated.

Note here that some buildings types are of an open design and do not require specialized access-ways. Other buildings are closed ("sealed") often for protection from the elements, insulation, and atmospheric conditioning efficiency. These buildings require specialized access-ways like doors and windows.

It is relevant to note here that there may be other types of access, including but not necessarily limited to:

1. Atmospheric access.
   A. Doors.
   B. Windows.
   C. Vents and ducts.
2. Non-atmospheric materials access.
   A. Pipes.

An access specification may include:

1. Access plan for users.
   A. Human access (walkway access)
   B. Animal access (pathway access)
   C. Vehicle access (driveway access)
2. Evacuation plan for users.
   A. Human evacuation
   B. Animal evacuation
   C. Vehicle evacuation
3. Catastrophe plan - area of refuge/safety requirements in case of catastrophe.

Access-ways for buildings include, but may not be limited to:

1. Based on direction.
   A. Bi-directional.
   B. Directional.
      1. Entraceway (a.k.a., ingress).
      2. Exit (a.k.a., egress).
2. Based on placement location.
   A. Gate - a gate is a hinged barrier used to close an opening in a wall, fence, or hedge.
   B. Door - a door is a hinged, sliding, or revolving barrier at the entrance to a building, room, or vehicle, or in the framework of a cupboard.

In the context of human walkable opening to and within buildings, there are more accessible, and less accessible designs. "Accessibility" refers to a concept that focuses on making buildings, especially homes, accessible and welcoming to all individuals, including those with mobility impairments or disabilities. It is not directly related to having a beautiful long view.

Accessibility in this context typically includes the following design principles:

1. No-step entry: The main entrance to a building should be at grade level or easily accessible through a gently sloped ramp, allowing people with mobility aids (such as wheelchairs or walkers) to enter without encountering steps.
2. Wide doorways and hallways: Doorways and hallways should be wide enough to accommodate wheelchairs and other mobility devices, typically at least 32 inches (80 cm) wide.
3. Easy to open doors: All common doors should either open automatically or be easy for a child to open.
4. Accessible bathroom: There should be accessible bathrooms on the main level, which includes features like grab bars, a roll-in shower, and adequate space for maneuvering.

26 Accessibility design optimization

A.k.a., Disability inclusivity, disability support optimization, accessible design, accessibility engineering.

Accessibility is the term most often used to refer to access to a building by someone with a disability. Accessible design is an approach to designing architecture that renders them easier to access and use by people with physical, sensory, or cognitive disabilities. Accessibility requires the inclusive provision of ease of access to, and circulation within, specific architecture (primarily, buildings), together with requirements for facilities for disabled people.

The following terms and factors are relevant to accessibility design:

1. **Accessible route:** A continuous and unobstructed path of travel that meets or exceeds the dimensional requirements.
2. **Visitability**: A structure that is designed intentionally with no architectural barriers in its common spaces (entrances, doors openings, hallways, bathrooms), thereby allowing persons with disabilities who have functional limitations to visit.
3. **Area requirements**: Areas with additional floor space that meet or exceed the dimensional and inclusionary requirements.
4. **Ideal design for accessibility**: Design that meets, as well as exceeds, compliance with accessibility building code requirements.

Note that under some conditions it is useful to design building units (e.g., dwellings) with features that can be modified without structural change to meet the specific functional needs of an occupant with a disability.

26.1 Accessibility design standards

A.k.a., Disability accessibility design.

Disability accessibility design provides access to architectural spaces for persons with disabilities.

Accessible design standards are often legislated by governments:

- In the United States of America, the Americans with Disabilities Act (ADA) is a federal law, passed in 1990, which prohibits discrimination against people with disabilities. The term "disability" means a physical or mental impairment that substantially limits one or more of the major life activities of such individuals. Among the provisions in the law are requirements that impact plumbing products in the design of accessible bathrooms and facilities. Herein, an ADA-compliant device is a device which is fully compliant, when properly installed, with the current requirements of the Americans with Disabilities Act Accessibility Guidelines (ADAAG), as legislated by the Americans with Disabilities Act of 1990.

27 Visual access optimization

A.k.a., Vision optimization, vista and privacy optimization, sitelines, atmospheric sitelines, etc.

In architecture and design, the term "scenic vista" or simply "vista" is used to describe a carefully planned and framed view of a visually pleasing or significant landscape or scene. Vistas views are often incorporated into architectural designs to take advantage of beautiful natural surroundings or to create specific visual experiences for occupants.

It is possible to design buildings with features like large windows, balconies, terraces, or open spaces strategically positioned to frame and showcase scenic vistas. The goal is to enhance the visual connection between the built environment and its surroundings, allowing people inside or around the building to enjoy and appreciate the natural beauty of the habitat and wild environment.

It is possible to reduce or enhance vision to architecture, and from architecture, by placing or removing barriers to human vision. Vision optimization involves:

1. Vision from architecture. For example, someone seeing a beautiful view from their home or some other building.
2. Vision to architecture. For example, someone seeing a building or view into a building.
3. Vision between architecture. For example, one building in front of another or no buildings in front of any other.

There are many different ways to shut out and open up human views. A preferred level and form of vision can be optimized by adding barriers, removing barriers, and appropriately positioning architectural objects so that vision is open and closed where preferable. For example,

1. In some cases, it is preferable to reduce visual access to buildings (e.g., personal dwellings) and building interiors by placing visual barriers (e.g., a hedge or row of trees) in front of the building.
2. In concern to high-density living, it is possible to reduce visual access to the interior of personal dwellings by not facing dwellings toward the face of other dwellings.
3. In some cases, it is preferable to remove plants to allow more light and/or vision into an area.

28 Safe access design optimization

A.k.a., Safe access engineering, safety.

Safe access design refers to the application of standards to ensure that occupants and machines are safe and protected from all of the following sources of danger:

1. **Falling** - refers to risk of people or objects descending from an elevated position to a lower level (via the force of gravity). It is crucial for designers to assess and mitigate falling hazards in buildings to ensure the safety of occupants and visitors. For instance, fall protection measures may include properly designed handrails, guardrails, and barriers on balconies, staircases, and raised platforms to prevent accidental falls.
2. **Collision** - refers to the potential for people or objects to come into physical contact with one another, with structural elements, or with various architectural features within a space. Architects must consider the layout and circulation paths within a building to minimize the risk of collisions and ensure smooth movement and functionality. This can involve designing clear pathways, avoiding sharp corners or obstructions, and considering visibility to prevent accidents.
3. **Impact** - refers to the forceful contact or collision of an object or a person with a building element or surface. Designers need to consider potential impacts in areas with heavy foot traffic or where equipment and machinery might be in operation. Impact-resistant design strategies may involve selecting durable materials, reinforcing vulnerable surfaces, or incorporating safety features to reduce the consequences of accidental impacts.

By understanding and addressing potential falling, collision, and impact risks, designers can create spaces that are not only aesthetically pleasing, but also safe and functional for the people who use them. Safe access standards should be followed in order to ensure the safety of all architectural elements, and in particular: stairways, ramps and ladders, together with requirements for balustrading, windows, and vehicle barriers. Also included are requirements for guarding against and warning of, hazards from the use and position of doors and windows. Also included are safety requirements relating to the use and cleaning of windows and other potentially risky surfaces.

NOTE: *Some safety systems are static and do not require removal when they are not in use. Other safety systems do not need to be permanently installed and can be disassembled when not in use.*

28.1 Collective restraints and barriers

Collective restraint systems protect occupants and workers. These include, but are not limited to:

1. **Guardrails** - a longitudinal barrier that prevents people from falling or straying into a dangerous or restricted zone.
2. **Barriers or guardings** - are structures that deny access to unsafe areas, and include raised rails, parapets, or walls.
3. **Purlin trolleys** - provide workers with a safety deck to walk on and protect them from exposure to edging. They are frequently used in roofing installations.
4. **Bollards** - protective posts that avoid vehicle collision on buildings and guard pedestrians at intersections.

28.2 Fall prevention and arrest systems

In concern to working, fall prevention systems (or fall restraint systems) are safety systems designed to stop personnel from falling when working at height. Ideally, this type of system completely eliminates the hazard by making it impossible to fall. Fall prevention systems are active systems, which means workers have to take action in order to be protected. This aspect differentiates them from collective restraint systems, which are passive and require no action on the part of the worker. Prevention systems use individual restraints to keep workers from falling. They incorporate customised harnesses connected to an anchor and safety line to keep workers from entering areas where hazards are located. Fall prevention systems must be replaced when necessary and must be maintained. Training is required for proper use. Note that a personal fall arrest system (FAS) is a system designed to minimise injury if a worker should fall from a significant height and experience impact. The purpose of the system is not to stop the fall (that is the purpose of a fall restraint system or fall prevention system), but to limit the injuries that could happen to a worker as a result of the fall's impact.

29 Security design optimization

A.k.a., Architectural service control, area control, defense design.

Security architecture is the term used to define the overall system required to protect someone or something. Security design addresses the safety requirements and potential risks involved in a certain scenario or environment involving architecture.

29.1 Presence signaling

Presence signaling devices signal an owner/occupant to the presence of someone or some thing at an accessway entrance or exit. There are two primary types of presence signaling:

1. Doorbells.
2. Motion sensors.

29.1.1 Doorbell

A doorbell is a signaling device typically placed near a door to a building's entrance. When a visitor presses a button a bell rings (inside the building or on a smartphone), alerting the owner/occupant to the presence of the visitor.

29.1.2 Motion sensor

A motion sensor is a device that senses the presence of motion and may send an alert to an owner/occupant.

29.2 Access security

A.k.a., Secure access design

Secure access design is intended to provide that reasonable provision must be made to resist unauthorised access to specific architectural areas (in particular, to dwellings), including any part of a building from which access can be gained to a home or secure space within the building.

29.2.1 Access control

Access control for a building includes both:

1. Accessway obstructions (e.g., doors and gates).
2. Locks.

29.2.1.1 Locks

A lock is security mechanism that secures an obstructed opening from intrusion.

There are two general types of door locks:

1. **Manual locks** - require physical access (e.g., physical key) and presence.

2. **Electronic locks** - require electricity.
   A. **Manual electronic locks** - require physical presence (e.g., access card or push button pin).
3. **Wireless electronic locks** - may be opened from anywhere.
4. **Directionality of locks** - how easily a lock can be opened.
   A. **One-way locks** - locks that cannot be easily opened from the insecure side.
   B. **Two-way locks (a.k.a., reversible locks)** - locks that can be easily opened from the insecure side.

Specific locks are used for specific situations; i.e., specific locks go on specific doors. For instance, permanent locks never go on bathrooms,and typically not beds or drawers in a personal residence. Typically the only location with a lock that cannot be easily opened in reverse is the perimeter home (front and back door) locks.

The main parts of a door lock are:

1. **The cylinder (lock body)** - the part of the door lock where the key is inserted or where an electronic motor is housed.
2. **The bolt or latch** - a piece of metal that extends from the door into the frame and holds it closed. There are two main styles of latch (or bolt) - a spring bolt and a deadbolt. When the lock is disengaged, the bolt is inside the cylinder.
3. **The box** - the bolt extends from the cylinder into a shaped hole ("box") inside the door frame.
4. **The strike plate** - a metal plate that attaches to the frame of the door. The purpose of the strike plate is to guide the bolt from the cylinder into the box of the frame and give added reinforcement to the locking mechanism.
5. **The key** - the variable that is identified with a user and will physical and/or digital [token code] open and close the lock.

Electronic access control systems (ACS) include, but are not limited to:

1. PIN codes.
2. Magnetic identity cards.
3. Proximity tokens.
4. Biometric devices.

30 Acoustics design optimization

A.k.a., Sound design, acoustics control engineering, sound control engineering, acoustic performance.

Sound is a series of pressure vibrations that move through an elastic medium. Its alternating compressions and rarefactions may be far apart (low- pitched), close together (high- pitched), wide (loud), or narrow (soft). All perceived sound has a source, path, and receiver. Each source has a size, direction, and duration. Paths can be airborne or structure- borne. Sound has four quantifiable properties:

1. Velocity.
2. Frequency.
3. Intensity.
4. Diffuseness.

Regarding velocity, sound travels much faster through solids than air (and faster through warm air than cool air). Frequency is sound's vibrations per second, or hertz (Hz). This varies according to its purity and pitch. The average human pitch for hearing is about 1000 Hz. Intensity is the power level (or loudness) measured in decibels (dB). Attenuation is the loss of a sound's intensity as it travels outward from a source. Diffuse noise (blanket or background noise level) is sound emanating from a multiple of similar sound sources. Sound has four quantifiable.

Sound travels through walls and floors by causing building materials to vibrate and broadcasts in resonant locations. There are two methods of setting up the vibration (through structure-borne sound and/or air-borne sound):

1. **Structure-borne sound** - the vibration of building materials by vibrating pieces of equipment, or caused by walking on hard floors.
2. **Air-borne sound** - a pressure vibration in the air, such as wind or other moving air. When the air hits a wall, the wall materials are forced to vibrate. The vibration passes through the materials of the wall. The far side of the wall then passes the vibration back into the air.

30.1 Acoustic requirements

In architecture, there are several requirements that deal specifically with acoustics:

1. Requirements for sound isolation during construction.
2. Requirements for sound insulation between buildings, including both new dwellings and the conversion of buildings to form dwellings.
3. Requirements for sound reduction between rooms

and apartments (i.e., between architectural spaces).
4. Requirements for sound reduction within a room.
5. Requirements for sound amplification in specially designated areas (e.g., theatres and concert halls).

30.2 The sound problem

Sound should be blocked from entering parts of a building and landscapes where it is not intended to enter. Sound should not be emitted from environments that it is not designed to be present in, ensuring acoustic comfort and minimizing disturbances.

The acoustic quality of an architectural space is related to both:

1. The ability to carry out the activities for which a space has been designed, and
2. Not having noise pollution problems (such as those related to reverberation and isolation).

It should not be forgotten that heavily equipped sound systems, or even certain lifestyles, can disturb neighbouring houses or even residents within the same household.

30.2.1 Sound pollution

A.k.a., Noise pollution, undesired propagating mechanical waves.

Sound pollution occurs anywhere sound is present and is unwanted. It is important to note here that sound can be a form of pollution. Sound pollution can include exterior sources of sound, such as outside construction and landscaping noises, or interior sources, such as a washing or drying machine. Sound pollution (as mechanical wave vibration) can range from a simple distraction (disturbance to rest and work) to a physical safety issue (damage to physical structures).

Noise prevention efforts, also known as sound propagation reduction efforts, aim to mitigate or reduce the transmission of sound in several key scenarios:

1. External to internal sound isolation: These efforts focus on preventing external sounds from entering a building, ensuring that the interior remains quieter and less affected by external noise sources.
2. Internal-to-external noise control: In this context, the goal is to block or dissipate sound that would otherwise escape from a building and affect the surrounding exterior environment. This helps maintain a peaceful outdoor space.
3. Intra-building sound control: Within a building, sound prevention efforts aim to prevent sound emitted from one room or area from unintentionally entering other rooms or spaces where it was not intended to be heard. This includes minimizing sound transmission between rooms and across different floors of a building.

Factors that affect sound pollution include, but are not limited to:

1. Low frequency travels farther than high frequency.
2. Adding sound:
   A. Sound cancellation (a.k.a., sound masking) - a sound masking/cancelling system takes in ambient sound, analyzes the frequency, and counters it by adding an opposing frequency of sound to effectively flatten it
   B. White noise - a noise that contains all frequencies across the spectrum of audible sound in equal measure. White noise uses a mix of sound frequencies to create a static-like sound that drowns out other sounds. Because white noise spans multiple bands of sound, it is sometimes referred to as broadband noise.
3. Sound absorbers.
4. Sound deflectors.

INSIGHT: *Noise pollution can reduce messages from nature, such as from birdsong.*

30.3 Acoustics control and design

A.k.a., Sound control, acoustics design.

For excellent and controlled acoustic performance, architectural design should be complemented by a well-executed acoustic engineering plan.

In concern to acoustics there are three general designs, some environments are designed:

1. To be expressive of sound, such as theatres and concert halls.
2. To control/inhibit the spread of sound.
3. Not intended to accommodate loud sounds.

To attain the desired acoustic performance, it's vital to distinguish between materials and their sound-related properties. Sound insulation, which aims to halt sound transmission, relies on factors like volume, mass, and density. However, creating an ideal acoustic environment goes beyond merely stopping sound propagation. It necessitates an understanding of the technologies generating sound within the environment and implementing sound absorption techniques to mitigate disruptive reverberation during sound-producing activities.

Sound control uses the properties of:

1. **Isolation (a.k.a., sound isolation, noise isolation)** - placement of sound producing equipment in isolated areas. When it comes to sound insulation

(preventing the spread of sound), it involves volume, mass, density, and porosity. An ideal environment requires sound absorption to prevent disruptive reverberation during activities

2. **Reflection** - large concave surfaces concentrate sound and should usually be avoided, while convex surfaces disperse sound.
3. **Diffusion** - providing uniform distribution. It is increased by objects and surface irregularities. Ideal diffusing surfaces neither absorb nor reflect sound but scatter it.
4. **Absorption** - provides the most effective form of noise control.
    A. Vibration isolation padding - can be placed under the feet of machines to reduce their vibration. A dryer and washing machine are examples of machines that can often create significant vibration.
    B. Noise dampening (a.k.a., sound dampening) materials - these materials absorb sound. Examples of noise dampening materials include, but are not limited to:
        1. Noise dampening foam.
        2. Rugs and carpets.
        3. Curtains and blinds.

Sound of any kind emitted within a room will be absorbed or reflected off the room surfaces. Soft materials absorb sound "energy", and hard materials reflect sound "energy" back into the space.

30.4 Cymatic science

Constructions on a landscape convey [acoustic] frequency information [to users of the habitat-construction system]. Hence, it is interesting to consider the acoustic (3D) depiction of a landscape, which necessarily necessitates different views of the acoustic nature of the habitat. Herein, cymatics is the study of perceptible (usually visual) sound vibration, showing the transformational nature of sound and matter. Essentially, cymatics is the scientific relationship between sound and form, which relates information about acoustic (mechanical) pressure induction. The idea is that for every acoustic vibration, be it audible or not, there's a predictable, repeatable pattern that is likely to form in matter. Vibrational sound tones (i.e., audio frequencies) reveal themselves (i.e., are visibly observed) as patterns of particles in a vibratory chamber. When the physical vibratory frequency is higher, the pattern is more complex. When the frequency is turned off or removed, the matter falls out of pattern. These instruments are call cymascopes. Cymatic patterns can be scientifically observed through a cymascope. It is possible to can re-create the archetypal forms of nature as acoustic frequency through cymatic processes programmed into cymascopes.

Consider that sound has form; it can affect matter and cause form between particles matter. Now consider the structural formation of a habitat (i.e., city system), and its continuous operation. And if we ponder on that, perhaps cymatics can provide useful data on the optimal formation of that city.

31 Fire and contaminant protection design optimization

A.k.a., Fire and contaminant protection engineering.

In concern to fires, this covers all precautionary measures necessary to provide safety from fires for construction and operation of architecture, including occupants, persons in the vicinity of buildings, and firefighters. Here, requirements and guidance covers:

1. Means of escape in cases of fire.
2. Fire detection and warning systems.
3. The fire resistance of structural elements.
4. Fire separation, protection, compartmentalisation isolation to prevent fire spread, control of flammable materials.
5. Access and facilities for firefighting.
6. Requirements to control fire sources and prevent burning, pollution, carbon monoxide poisoning, etc.

Fire and atmospheric danger prevention and resistance includes:

1. Fire safety/warning system (smoke alarms) - Each dwelling must have smoke detectors in each sleeping room and the corridor to sleeping rooms, at each story (close proximity to stairways), and basement.
   A. Safety and alarm requirements
      1. Fire detection and/or suppression requirements
      2. Gas hazard detection

Normal atmospheric-type of detectors found in many buildings:

1. Smoke detector
2. Gas detectors can be used to detect combustible, flammable and toxic gases, and oxygen depletion.
   A. Carbon monoxide detector - build-up of carbon monoxide is dangerous.
   B. Natural gas - leakage is dangerous (e.g., propane, butane, methane, etc.).
   C. Low oxygen - presence of low oxygen is dangerous.
3. Radon detector
4. Other site related hazardous and dangerous substances.

These detectors are connected to an alarm system that alerts occupants and others to:

1. Leakage - for example, toxic and flammable gases.
2. Build-up - for example, carbon monoxide.
3. Depletion - for example, oxygen.

It is important to have control protocols for toxic substances, during both the construction (including demolition) and operation of architecture.

31.1 Interior and exterior fire sources

Fires can inside architecture and can also spread to architecture from outside sources.

1. Is there a risk of fire coming from some direction?
2. What direction does the wind mostly come from?

31.1 Fire and contaminant protection requirements

The optimization of several architectural elements can optimize the reduction and elimination of fires; optimization requirements for fire (and contaminant protection) may include, but are not limited to:

1. Optimization of infrastructural interiors, including fixtures, fitting and appliances.
2. Optimization of furniture so that they do not interfere with potential fire producing infrastructural services..
3. Optimization of illumination so that sunlight doesn't cause quick light damage.
4. Optimization of landscape to reduce the likely appearance and spread of fire.
5. Optimization of safety mechanisms to ensure that fires can be effectively resolved in a relatively short amount of time and with as little damage and harm to life as possible.

31.2 Optimization of a landscape to reduce the likelihood of fire and its spread

Landscapes are areas where fires have the potential of appearing. Therein, it is important to arrange and caretake plants. Careful placement of plants can significantly reduce the impact of fire. The immediate area around buildings should be free of trees and other combustible materials. It is possible to create effective barriers to the spread of fire by means of well watered lawns, paved areas, driveways, fire breaks between trees, etc.

Fire protection principles include, but are not limited to:

1. Distances from buildings: Keep trees at least the same distance as the height of the mature tree from any buildings, for example if the height of a particular tree is 20 metres when fully grown, then it should be planted at least 20 metres away from

any building (if the tree falls, then burning branches won't hit the building).

2. Consider prevailing winds: The prevailing winds will affect the way fires will travel and where ash and burning embers fall. It is important to note that prevailing winds may vary from season to season, although days of extreme fire danger are usually characterized by hot gusty winds with southerly wind shifts later in the day.
3. Consider vehicular access: Access routes to dams, pumps, roads etc. should be kept free of trees and flammable material. This includes all routes of escape.
4. Maintenance: Points to Remember: Water trees in summer (keep moisture in the plant high)
5. Fertilize plants: Regularly fertilize. A plant that has lush green growth is less likely to burn.
6. Have water available: Have a water hose ready at all times, and ensure water is readily available.
7. Only use mulches that will not burn readily.
8. Remove dead woody material: Remove twigs, leaf litter, branches, etc. from the ground. A compact mulch of stone or even food shavings is not generally a problem, but leaves and twigs can be, in a bushfire. Leaf litter can be dug in or composted to prevent it burning.
9. Remove flaky loose bark from trees: Smooth barked trees are less likely to catch fire.
10. Prune lower branches: so that burning debris under plants can't ignite foliage.
11. Remove dead trees and fallen branches.
12. Fill hollows/cavities (hollow trunks, depressions where branches break & rot gets in) with concrete or remove the plant...fire can catch in such hollows and the tree may smoulder for some time without you knowing it.
13. Avoid large dense clumps of trees & shrubs particularly near buildings.
14. Have succulent ground cover, lawn or gravel under large trees or regularly slash or cut any underlying scrub and grass to remove potential fuel for fires.

32 Pest control design optimization

A.k.a., Pest control engineering, urban entomology control.

A pest is either a destructive insect or animal that attacks and damages the architectural construction and/or is a nuisance to human occupants. Therein, there are two categories of pests in relation to architectural constructions:

1. Pests to the materials used to construct architectural objects.
   A. Termites.
   B. Wasps.
   C. Rodents and other mammals.
   D. Birds.
   E. Mites and silverfish
2. Pests to humans.
   A. Biting and stinging insects.
      1. Mosquitoes.
      2. Ants.
      3. Biting flies.
      4. Spiders.
      5. Wasps
   B. Non-biting insects.
      1. Flies.
   C. Rodents and other mammals.

The best method of pest prevention is prevention by design of the architectural construction itself. Pest proofing in conjunction with sanitation efforts provides the best long-term management of urban pest infestations. Building codes generally require some of the more common procedures of pest control (e.g., screening foundation vents), but often do not go far enough in facilitating the design of buildings and landscapes that sufficiently reduce or eliminate pests.

It is important to understand local pest pressures when localizing architecture. Climatic factors and bio-regions limit the distribution of many pest organisms. Generally speaking, insect pests are most troublesome in warm, humid climates. Warm temperatures speed up insects' life cycle, resulting in higher populations. (Geiger, 2012:11)

Animals of all kinds, whether vertebrate or invertebrate, are living organisms with biological needs and behavioral preferences. All require the following in order to take up residence and become pests (Geiger, 2012):

1. Food.
2. Water.
3. Harborage.
4. Entry.

Eliminating just one of these factors can be sufficient to prevent infestations. All of the pest prevention tactics listed herein are based on minimizing these factors.

32.1 Pest control design considerations

When designing for pest control and deterrence, the following principles should be considered (Geiger, 2012):

1. Understand the local pest pressures.
2. Analyze the physical context (function and local surroundings) of the building.
3. Design for the necessary pest tolerance level.
4. Use durable pest-resistant materials.
5. Design for easy inspection.
6. Minimize moisture.
7. Seal off openings.
8. Eliminate potential harborage.
9. Engineer slabs and foundations to minimize pest entry.
10. Engineer access-ways to minimize pest entry.
11. Design buildings to be unattractive to pests.

32.1.1 Pest tolerance level

The tolerance to pest infestations varies by architectural function, and ideally should be considered at the design stage. An occasional trail of ants in the home may be a mere nuisance, but even a single ant in a surgical ward can have grave consequences. Institutional kitchens, health care facilities, and mission-critical manufacturing facilities demand detailed and careful design and planning to exclude potential pests. (Geiger, 2012:13)

32.1.2 Pest control methods

Pest control methods for the material used in architectural constructions include, but may not be limited to:

1. Pest-resistant buildings reduce not only pest problems, but also the need for pesticide applications.
    - A. Select pest resistant materials:
        1. Using materials that pests do not consume (e.g., concrete, specific types of wood).
        2. Treating (impregnating, pressure soaking) materials that pests would otherwise consume with toxins (e.g., wood soaked in a toxin). Note here that if/when these buildings catch fire their combustion can be more toxic because of the compounds they are impregnated with (i.e., soaked in), and the toxins can leach into the local environment.
            - i. For example, chromate copper arsenate (CCA) treatments pose cancer and reproductive hazards to workers and the public, while compounds with high copper content (such as amine copper quat, ACQ) pose higher aquatic toxicity hazards. (Dickey, 2003)
            - ii. Borate treatments are viable alternatives for interior use, or situations with low exposure to moisture, which can leach the material out of the wood.
            - iii. Silicates.
    - B. Sealing off access areas:
        1. Screening of vents.
        2. Sealing all gaps.
    - C. Removing sources of intrusion, such as dense vegetation proximal the architecture, to reduce intrusion from a variety of small mammals, such as rats, mice, chipmunks, ground squirrels, raccoons, opossums, and tree squirrels.
    - D. Adding harborage disruption elements (e.g., spikes to prevent bird roosting).
2. Pesticides (insecticides).
    - A. Distributed within the building (e.g., within the attic or basement).
    - B. Distributed in the grounds around the building.

Pest control methods for rodents include, but may not be limited to:

1. Rodenticides.
2. Mechanical traps.
    - A. Capture alive traps.
    - B. Kill traps.
3. Rodent impervious constructions.

Pest control methods for insects include, but may not be limited to:

1. Repellents for airborne pests:
    - A. Repelling plants.
        1. Catnip plants.
        2. Citronella plants.
    - B. Repelling gases and odors.
        1. Citronella candles.
    - C. Repelling by means of rapid movement.
        1. Fans - rapidly moving air will deter airborne pests.
2. Mechanical dislodging of airborne pests and their nests:
    - A. Brush to rid area of a nest.
    - B. Vacuum to rid area of nest.
    - C. Pressure washing to rid area of a nest.
3. Traps for airborne pests:
    - A. Traps with gas - A machine that transforms propane into carbon dioxide, which attracts mosquitoes, and then, captures them.
    - B. Traps without gas:

1. Glue paper.
2. Mechanical trap.
3. Bug lightbulbs.

4. Traps for ground-based pets:
   A. Insecticide traps for ants.
   B. Insecticide traps for cockroaches.

NOTE: *Ultrasonic rodent and insect "repellent" devices have generally been shown to be ineffective as deterrent agents and are not listed above.*

Techniques for pest prevention in architectural design include, but are not limited to (Geiger, 2012:13):

1. Intrusion prevention:
   A. Screen vents, tunnels, pipes, etc., to prevent intrusion.
   B. Remove intrusion sources, such as carpet-style ground cover and vines.
   C. Fill in architectural gaps.
      1. Seal off all openings to the building exterior, as well as openings between interior rooms.
      2. Use elastomeric sealant to seal small cracks, gaps around countertops, or pipe breaks against insect entry; stainless steel wool and fire block foam can be used for larger openings.
      3. Use escutcheon plates around all pipes where they enter through walls is essential.
      4. Foundation expansion joints can be safeguarded against termites with stainless steel mesh.
   D. Install tight fitting fixtures.
      1. Install doors with minimal gaps, including functioning door sweeps where necessary.
      2. Install tight fitting windows.
2. Reduce standing water and moisture to eliminate harborage and material decay.
   A. Reduce moisture in the building. Moisture promotes building decay, moisture also promotes serious problems with insect pests such as termites, wood-boring beetles, cockroaches, flies, carpenter ants, silverfish, and millipedes, to name but a few. Perhaps even more important, excessive moisture inside buildings can lead to serious mold contamination issues—some of which can require many thousands of dollars in remediation. Multiple procedures can be used to minimize building moisture including proper guttering, downspout placement, correct ventilation of crawl spaces, one-piece countertops, humidistats, vapor barriers for crawl space flooring, appropriate slopes for patios, etc.
   B. Do not leave standing water on the architecture or surrounding landscape. Standing water is a breading habitat for mosquitoes and other insects. Ponds can be configured to have moving water by installing a solar powered pump, aeration system, waterfall, fountain, etc. In other words, add a device to ponds that moves the water around and/or circulates it so that mosquitoes will avoid breeding in it. Fish are another effective deterrent to mosquitoes. Additionally, micro- and macro-invertebrates will graze on mosquitoes, reducing their population.
3. Reduce the presence of pests on the surrounding landscape.
4. Clean refuse containers sufficiently.
5. Use durable pest-resistent materials. Selecting pest-resistant materials can exclude pests from entering a structure, or deny pests harborage once they are there. Some materials provide resistance to pests while other materials provide exclusion.

Material specifics for pest control include, but are not limited to (Geiger, 2012):

1. Pressure treated wood.
2. Stucco - resistant to insect penetration from the outside, is generally a poor choice in high termite pressure areas for two reasons:
   A. When improperly constructed, moisture can accumulate in the enclosed wood.
   B. The stucco shell makes inspection virtually impossible.
3. High-density plastic - will deter gnawing by rats and mice, and neither rodents nor insect pests are likely to penetrate high quality elastomeric sealant compounds when applied correctly.
4. Stainless steel mesh carpeting material - deters rodents from burrowing into soil to gain access.

32.1.2.1 Insecticides (pesticides)

Boric acid (borax) is most often used in pesticides, and can be found in tablet form, liquid form, powder form and in various types of traps. It is a natural salt and is one of the oldest inorganic compounds known to mankind in treating pests; it is generally considered a natural and non-toxic insecticide. It is a mined substance. Boric acid and its sodium salts can be used to control a wide variety of pests; these include: insects, spiders, mites, algae, molds, fungi, and weeds. It kills insects by absorbing into them, poisoning their stomachs, affecting their metabolism, and also, abrading their exoskeletons causing them to dehydrate (dry out). Boric acid is a white or colorless powder that can be used as an insecticide, herbicide or fungicide. Note that boric acid can also be used as an abrasive when cleaning with water. Boric acid dust should not be breathed in by humans and is dangerous to human lung tissue. Cockroaches may be killed by dehydration after running through boric acid powder. Ants that consume boric acid powder mixed with feed (e.g., sugar) will be killed after ingestion.

A commonly used and simple boric acid treatment for an insect infestation is as follows:

1. Ingredients:
   A. 1 tbs of boric acid.
   B. 1 tbs of sugar.
   C. 4 oz water.
   D. Cotton balls.
2. Recipe:
   A. Mix the boric acid and sugar in a bowl.
   B. This mixture can be poured over an area, or over a cotton wad.
   C. In the case of the usage of cotton, place the cotton balls in the path of the insects.

32.2 Architectural pest avoidance design practices

The following architectural design practices will reduce pests. The following architectural design elements should be accounted for (Geiger, 2012):

1. Landscape.
2. Foundations and slabs.
3. Building exterior: siding.
4. Building exterior: wall and perimeter.
5. Building exterior: lighting.
6. Roofs.
7. Interior walls.
8. Floors.
9. Doors.
10. Windows.
11. Bedrooms.
12. Bathrooms.
13. Kitchens: general.
14. Kitchens: institutional.
15. Utilities, HVAC, and chutes.
16. Refuse and recycling.
17. General area.

32.2.1 Landscape

32.2.1.2 Design and maintain landscape areas near buildings to minimize the number and types of pests

1. Tree branch maintenance.
   A. Maintain at least 6 feet of clearance between exterior walls and tree limbs/branches that might provide vertebrate pest access (3.048m if tree squirrels are a problem).
2. Fruit trees that are attractive to pests.
   A. Use plants that shed a minimum of seeds and fruits, since the seeds and fruit may attract and support insects, rodents, and undesired birds.
3. Landscape plants that are attractive to rats.
   A. Avoid planting Algerian or English ivy, star jasmine, and honeysuckle on fences or buildings, as they provide shelter and food for rats.
4. Landscape plants that are attractive to ants.
   A. Where Argentine ants are common, avoid bamboo, cherry laurel, fig, pine, and roses near buildings. These plants often have abundant scale and aphid populations, and excreta from these insects provides food for ant colonies.
5. Plants with dense canopies.
   A. Separate the canopy of densely growing plants from one another and from buildings by a distance of 0.6m or more to make it more difficult for rats to move between them.
6. Wood mulch.
   A. Decorative wood chips and mulch should be used sparingly in situations where termite infestation is a high probability. Wood chips should never be allowed to contact wood siding or framing of doors or windows. Crushed stone or pea gravel are alternative solutions and may also discourage ants and spiders.

32.2.2 Foundations and slabs

32.2.2.1 Drainage design

1. Slope of concrete and asphalt areas near buildings.
   A. Provide 6.35mm slope at patio slabs, walks, and driveways away from building.
2. Backfill around foundations.
   A. Tamp backfill to prevent settling and slope the final grade away from the foundation at a rate of 1.27cm per 0.3m over a minimum distance of 3.04m.

32.2.2.2 Reduce moisture in crawl spaces and under concrete slabs

1. Vents maintenance.
   A. Air should flow freely (not blocked by shrubbery, mulch, or other landscape materials) through vents to reduce moisture levels. Maintain vent openings to crawl spaces.
2. Subgrade membranes under concrete slab foundations.
   A. Use a continuous, durable subgrade membrane sealed at all splices, perimeters, and protrusions in order to minimize foundation moisture

problems. The membrane product selected should be specifically manufactured for use as a subgrade membrane and conform to ASTM E1745, latest edition, 0.1 perm maximum. Installation should conform to ASTM E1643, latest edition.

32.2.2.3 Prevent pest access to crawl spaces

1. Corrosion resistant, pest-resistant mesh on crawl space vents.
   A. For any ground-level space (e.g. raised foundation crawl space) requiring foundation vents, specify corrosion resistant vent material (e.g. bronze) and a vent opening size smaller than the pest to be inhibited. For example, for typical ants and termites, use #50 bronze mesh between layers of 12.7mm to 25.4mm mesh for durability. Building codes generally require mesh with maximum opening of 6.35mm, which will block rodent access.
2. Clearance between crawl space ventilation and finished ground level.
   A. Foundation vents should be at least 150 mm above finished ground level.

32.2.2.4 Access for inspections in the design of accessory structures that abut the foundation sidewall or other structures

1. Clearance at accessory structures.
   A. Provide 45.72cm clearance beneath and 15.24cm clearance between accessory structures and exterior wall coverings at decks, fences, patios, planters, and other accessory wood structures. If this clearance is not possible, construct accessory structures so that they are easily removable to allow inspection for termites.
2. Access to foundations.
   A. Provide easily removable components to allow access to foundation for inspections.
3. Concrete substructures.
   A. In order to minimize entry of pests via joints, pour concrete patios as part of the main slabs.

32.2.2.5 Eliminate wood and cellulose-containing material under and near structures

1. Wood material adjacent to building.
   A. No cellulose-containing material (wood scraps, form boards, vegetation, stumps, large dead roots, cardboard, trash, and foreign material) should be buried on the construction site within fifty feet of any building, especially in areas with high termite pressure.
2. Fill material.
   A. Fill material used around structures should be clean and free of vegetation and cellulose material.
3. Remove wood materials from masonry
   A. Prior to concrete placement, clean all cellulose-containing material from cells and cavities in masonry units to inhibit termite colonization.
4. Remove extraneous wood materials after foundation construction.
   A. After all foundation work is completed, remove all loose wood and debris from the crawl space and within 0.3048m of the perimeter of the building.

32.2.2.6 Consider termite susceptibility in choice of foundation materials

1. Steel posts in post and beam foundations.
   A. Use steel posts for post and beam foundations, especially in areas with high termite pressure. The ends of the posts should be sealed at both ends with welded plates and the posts should be set in concrete foundations.
2. Synthetic stucco.
   A. In areas of high termite hazard, avoid Exterior Insulation and Finish Systems (EIFS, commonly referred to as synthetic stucco).
3. Foam insulation and foundation systems.
   A. In areas of high termite hazard, avoid subgrade foam insulation on the exterior of the foundation, or pre-formed closed cell foam foundation systems.

32.2.2.7 Minimize cracks more than 1 mm wide in concrete foundations and slabs

1. Expansion joints.
   A. Minimize need for expansion joints when designing slabs. When expansion joints are used, inspection access should be readily available and the use of termite-resistant mesh should be considered. In one study, 83% of subterranean termites entering buildings came in through expansion joints in concrete slabs.
2. Voids in concrete.
   A. In order to minimize voids in concrete slabs, mechanically compact concrete with a vibrator when pouring a slab.
3. Curing of concrete slabs.
   A. Cure concrete slabs slowly to reduce shrinkage and cracks. Moist curing periods should generally not be less than seven days. Consult a structural engineer for design standards.
4. Anchors in concrete slabs.
   A. Embed anchor bolts in slabs as the slab is poured. If additional anchors are necessary, use adhesive anchoring systems rather than

expanding fasteners to avoid causing cracks.

5. Topical curing compounds for small foundations.
   A. For foundations and slabs up to about 15.24m in dimension, use liberal applications of topical curing compounds to decrease cracking.
6. Topical curing compounds or shrinkage admixtures for intermediate sized foundations.
   A. For foundations about 15m to 30m in dimension, use adequate concrete reinforcing and proper concrete mix design, placement, finishing, and curing techniques. Additionally, use a shrinkage limiting concrete admixture.
7. Topical curing compounds or shrinkage admixtures for large foundations.
   A. For foundations greater than about 30m in dimension, use adequate concrete reinforcing and proper concrete mix design, placement, finishing and curing techniques. Additionally, use a properly designed, shrinkage compensating concrete admixture.
8. Integrated slabs are preferred. If joints are necessary, consider termite barriers.
   A. Concrete slab foundations should be monolithic (floor slab integrated and poured simultaneously with footings). Unplanned construction joints should be minimized. In areas of high termite pressure any joints should be protected with mesh barriers or sand (graded stone) barriers. Mesh barriers should be laid on top of the vapor barrier and have a 15mm accordion fold under the joint. Edges should be turned up 25mm to be cast into the slab. The accordion fold should be protected by a strip of vapor barrier material so that the concrete does not bond to the accordion fold. Alternatively, a mesh barrier with an accordion fold can be parged to the top of the slab. Sand barriers should be confined within a void adjoining the joint that is at least 75 mm deep and at least 50 mm wide. A retainer cast into the slab should be used to confine the sand particles.

32.2.2.8 Reduce opportunities for undetected termite access

1. Visual access of upper edges of concrete slabs.
   A. The upper 100mm of the edges of a slab should remain exposed at all times; it should not be concealed by masonry, timber, soil, paving, etc.
2. Avoid indentations in edges of concrete slabs.
   A. The vapor barrier underneath a slab should end no higher than the level of the finished soil or paving level. Slab formwork should include 100mm of smooth faced timber around the top of the slab edge. The purpose of these construction details is to avoid indentations which allow undetected termite access.

32.2.2.9 In areas of high termite hazard use shields or barriers with concrete slabs and foundations

1. Appropriate materials and designs for termite shields.
   A. If termite shields are used to reduce subterranean termite damage, they should be constructed of galvanized steel at least 0.5 mm thick; sheet copper at least 0.4mm thick; stainless steel at least 0.4mm thick; aluminum alloy at least 0.5mm thick; copper and zinc alloys at least 0.5mm thick; or woven stainless steel mesh. Joints and corners should be mitered and soldered, welded, or brazed. Shields should extend 70-80mm past the foundation or foundation component. The last 30 mm of the shield should be bent downward at a 45 degree angle to reduce injuries during inspection. In addition, corners should be rounded. The slippery metal of termite shields provides a poor footing for termites and their tubes, although there is controversy about their effectiveness. Termite shields are also useful for inspection purposes to spot signs of infestation. The shields should be constructed with no gaps for termite access, and in settings that permit inspection.
2. Mesh barriers for termite exclusion
   A. When stainless steel mesh is used as a termite barrier, the mesh should be made from grade 304 or 316 wire with a minimum diameter of 0.18mm. The maximum aperture size should be 0.66mm x 0.45mm. This maximum size should be reduced if local termite species are known to be small. As necessary the mesh should be parged to concrete foundations with a grout consisting of water-dispersed copolymer, type GP Portland cement and sieved aggregate that can pass through the stainless steel mesh. The mesh should not contact dissimilar metals that will produce a corrosion reaction. If pieces of mesh need to be joined, the joint should consist of an area 10-15mm wide where the edges of the two pieces are folded together 2 1/2 times or a parged area 35mm wide where the pieces overlap. Mesh can be used as a perimeter barrier for masonry exterior walls when parged to the concrete slab, draped across the cavity, and then built into the exterior wall. It can also be used as a continuous barrier under concrete

slabs, or as a barrier under joints and for utility penetrations.

3. Sand or basalt barriers for termite exclusion.
   A. Where graded particles (sand or basalt) are used as a termite barrier, the particles should be graded and shaped so that a sufficient proportion of them are of a size that cannot be transported by local termite species. They also should be able to be placed so that voids between particles to not permit penetration of local termite species. They can be either igneous or metamorphic stone. The wet/dry analysis must have less than 35% variation and their specific gravity must be at least 2.52. Graded particles can be used as a perimeter barrier when installed in wall cavities or in a trench around the foundation. In either case the minimum depth of the particles should be 75 mm. Trenches should be at least 100 mm wide. Graded particles can also be used as a continuous under-slab barrier. These barriers should be 75-100mmm deep and compacted with a vibrating plate-type tamper. Graded particles can also be used as a barrier under joints and around utility penetrations. Appropriate diameters for particles are 1.2-1.7 mm for the western subterranean termite, 1.7-2.8mm for the eastern subterranean termite, and 1.7-2.4mm for the Formosan termite.

32.2.2.10 All points where utilities go through the slab should be readily accessible for inspection. Gaps between penetrations and slab should be sealed using epoxy as a sealant, mesh barriers, or sand barriers.

1. Epoxy sealants for utility breaks.
   A. Use epoxy immediately prior to pouring a slab to seal concrete around utilities.
2. Mesh barriers for utility breaks.
   A. Mesh barriers should consist of a flange of mesh 50mm wide. The mesh flange should be attached to the penetrating utility with a stainless steel clamp and embedded in the slab. Alternatively, the mesh flange can be attached with a stainless steel clamp and then parged to the top surface of the slab.
3. Sand barriers for utility breaks.
   A. For sand barriers, concrete should be poured in a circular area 25mm around the utility pipe. That void should then be filled with sand at least 75mm deep. The sand should be capped at the top of the slab, and a retainer cast into the slab below the sand should be used to prevent sand loss beneath the slab.

32.2.2.11 Maintain adequate clearance between wood foundation components and soil.

1. Minimum clearance.
   A. There should be a minimum clearance of 45.72cm between beams or joists and soil.
2. Increased minimum clearance.
   A. In areas of high termite hazard, clearance between beams or joists and soil should be 91.44cm.

32.2.2.12 Use "curtain walls" around and below a foundation where necessary

1. Effective designs for curtain walls.
   A. Rats often burrow under foundations of buildings without basements. Vertical curtain walls 0.6m below the surface with an 20cm horizontal "L" or flange directed away from the building are usually effective in preventing rats from burrowing under foundations. Construct curtain walls of 29-gauge corrugated iron, concrete, or bricks.

32.2.1 Building exterior: siding

32.2.1.1 Install and finish siding to minimize gaps, warping, and cracking

1. Caulk and sealant for siding installation.
   A. On siding, use high quality, exterior grade caulks and sealants that meet ASTM standard C-920. Caulk should be compatible with both siding materials and trim materials.
2. Areas to be caulked or sealed during siding installation.
   A. Caulk or seal the following areas: wherever siding meets trim, around windows and doors, and around any penetrations (pipes, wires, etc.) that are not self-flashing.
3. Back flashing at siding butt joints.
   A. Use back flashing at siding butt joints to minimize openings that might allow entry of pests.

32.2.1.2 Provide sufficient clearance between siding and soil

1. Siding or stucco installation.
   A. Siding and stucco should begin at least six inches above soil level. This decreases the risk of subterranean termites reaching the wood, and makes their mud tubes more visible to inspectors.

32.2.2 Building exterior: wall and perimeter

32.2.2.1 Direct rainwater away from walls

1. Discharge from downspouts and gutters.
   A. To minimize moisture accumulation, all downspouts and gutters should discharge at least 0.3048m away from structure wall, using a connection to storm sewers, tail extensions, splash blocks, or dry wells.
2. Placement of gutters with downspouts.
   A. Use gutters with downspouts on all buildings with eaves of less than 15.24cm of horizontal projection except for gable ends and roofs above other roofs.

32.2.2.2 Prevent rodents from using downspouts and pipes to climb up exterior walls

1. Flap valves or mesh on downspouts.
   A. In areas of high rodent pressure, use flap valves to prevent rodents from entering downspouts. Mesh is also an option, but periodic cleaning will be necessary.
2. Cones and discs.
   A. In areas of high rodent pressure, use cones or discs (typically metal) to prevent rodents from traveling up downspouts and pipes. Cones should be mounted with the wide end of the cone facing down and should be 30.48cm in diameter and 30.48cm long. Discs should be 18 inches in diameter.
3. Vertical pipes.
   A. Prevent mice and Norway rats from climbing on exterior vertical pipes by applying a 45.72cm band of glossy paint around the pipe.
4. Strainer leaf guards.
   A. Use expanded strainer leaf guards (made for keeping leaves out of downspouts) to keep rodents from entering open pipes.

32.2.2.3 Design building perimeter to be unattractive to pests

1. Gravel strip around perimeter of foundation.
   A. To discourage rodent burrowing, install a gravel strip of 0.5cm diameter or larger, laid in a band at least 60cm wide and 15cm deep.
2. Plant-free strips around structures.
   A. Maintain plants, grass, and mulch several inches away from the foundation of buildings to minimizing nesting sites for ants.
3. Exterior landscaping.
   A. Design exterior landscaping so it does not cause moisture build-up around the foundation. Consider use of drip irrigation. Maintain clearances between vegetation and exterior walls.

32.2.2.4 Design accessory structures, fences, posts, planter boxes, and stairs to minimize termite problems

1. Contact between accessory structures and the main building.
   A. Construct decks, fences, patios, planters, or other wooden structural components that directly abut the sidewall of the foundation or structure to provide: (a) an 45.72cm clearance beneath the component, or (b) a 15.24cm clearance between the top of the component and the exterior wall covering, or (c) have components that are easily removable by screws or hinges to allow access for inspection of the foundation sidewall.
2. Termite-resistant fence and post materials.
   A. Use termite-resistant fence and post materials, including naturally durable wood, concrete and steel.
3. Wood steps above grade
   A. Wood steps should rest on a concrete base at least 15.24cm above grade to minimize access by wood-destroying pests, particularly in areas with high termite pressure.

32.2.2.5 Prevent animal access under sheds, decks, and porches

1. Use of metal mesh.
   A. Install quality 0.635cm or 1.27cm galvanized hardware cloth from the bottom of the shed/porch/decks without perimeter foundations to 7.62-10.16cm below the ground and then out in a perpendicular fashion at least 30.48cm from the vertical line. To improve appearance of hardware cloth used under sheds, decks, and porches, cover with lattice after installation.

32.2.2.6 Design and construct exterior building surfaces to minimize pest access to interior

1. Holes or joints in exterior or other cavity walls.
   A. Seal all holes or joints in exterior or other cavity walls that are larger than 6.35mm diameter to prevent access by mice. Where larger holes or joints are necessary they should be screened with 6.35mm mesh or otherwise shielded from pest intrusion. Seal smaller holes to eliminate access from smaller pests. Use caulk (non-elastomeric, does not return to original shape when stretched or compressed) for openings of 6.35mm diameter or less. Use an elastomeric sealant to close larger openings. Use a liquid sealer to close pores and hairline cracks.

2. Concrete masonry unit walls.
   A. "Cap" concrete masonry unit walls by filling the top row of blocks with cement to eliminate rodent access to the interior of the wall.
3. Sealing along foundation for standard stucco weep-screed construction.
   A. For standard stucco weep-screed construction, seal along foundation with 15.24cm minimum rubberized asphaltic, self-adhesive membrane extending down over foundation 2.54-5.08cm. At point above screed section, also seal back of flashing to foundation with generous bead of foundation mastic. Use vinyl weep screed in corrosive environments.
4. Appropriate flashing for stucco walls with offset weep-screed.
   A. For offset weep-screed installation use weep-screed flashing with offset in the flashing equal to actual framing offset. Install per standard weep-screed construction procedures except use 8-inch minimum self-adhesive membrane extending to bottom of weep-screed. Use small bead of caulking between base of framing and flashing.
5. Sealing for stucco walls with offset framing and standard weep screed.
   A. For offset framing where standard weep screed was used, install closed-cell-foam backing rod between foundation and flashing. Apply suitable, vertical application and resilient caulking between foundation and flashing. Alternatively fill gap between foundation and flashing with self-adhering, expanding foam. Upon cure, trim flush with base of flashing.

32.2.2.7 Design building exterior to minimize attractiveness for roosting birds

1. Design exterior structures to minimize bird perching, roosting, or nesting.
   A. Design exterior structures like decorative screens, moldings and lattices, siding, awnings, window sills, signs, fire sprinkler pipes, and column capitals so that they do not provide opportunities for bird perching, roosting, or nesting especially near building entrances. Use smooth materials and avoid horizontal surfaces. Where necessary, retrofit existing structures with exclusion devices (looped wires, sheet metal spikes, springs, nets, etc.), although these devices are not foolproof and require maintenance. Openings in buildings, exposed rafters on overhanging dock roofs, or any likely perches in semi-enclosed areas can be screened with rust-proof, 1.905cm wire or plastic mesh, or 1.27cm mesh to also exclude rodents. Plastic netting is less durable and must be replaced more often.
2. Avoid semi-enclosed spaces or alcoves.
   A. Semi-enclosed alcoves or courtyards, especially with open roofs, provide ideal roosting and nesting opportunities for pigeons and other birds. If these structures must be included in the building design, include bird barriers and minimize horizontal surfaces.

32.2.3 Building exterior: lighting

32.2.3.1 Choose exterior light fixtures to discourage bird roosting and nesting

1. Bird-resistant light fixtures.
   A. Choose light fixtures with sloping surfaces rather than horizontal surfaces to deter bird roosting and nesting.
2. Bird deterrents on light fixtures.
   A. Install bird spikes, "porcupine wire," netting, or similar devices to discourage birds from nesting on light fixtures.
3. Bird exclusion devices.
   A. Use bird exclusion devices, including wires, springs, nets, and electrical strips, to prevent birds from reaching light fixtures.

32.2.3.2 Design and install exterior light fixtures to minimize attraction of flying insects

1. Motion detectors on exterior lights.
   A. Motion detectors allow lights to be on for shorter amounts of time and can reduce accumulation of insects around lights.
2. Timers on exterior lights.
   A. Use timers to restrict light operation to high traffic times as appropriate. This may reduce the volume of insects attracted to the lights.
3. Reflected light rather than direct light.
   A. Use reflected light rather than direct light to illuminate doorways, as appropriate and allowed by local codes. Insects are more attracted to point sources of light and are therefore less likely to enter doorways.
4. Direct exterior lighting only for essential areas.
   A. Minimize direct lighting to high priority areas that maximize resident safety, especially near structures. All such lighting should meet local code requirements. This will minimize insect attraction to point source lights.
5. Yellow or red exterior lights.
   A. Use yellow or red lights ("bug" bulbs or sodium vapor lights, for example) in exterior areas where insect attraction to lights is an issue.

Both intensity and color are important in insect attraction.

32.2.4 Roofs

32.2.4.3 Construct roofs to reduce pest access into the building structure

1. Bird stops on tile roofs.
   A. Fit eave roof tiles with commercially available bird stops, which also exclude bats and flying insects.
2. Screens for attic vents and chimneys.
   A. Attic and chimney screens can prevent problems with bats, squirrels, and birds. In areas of where drywood termites are known to be a problem, consider replacing screens on attic vents (typically 6.35mm) with window screening. This may not be appropriate in damp climates, because the smaller mesh screening can impede air flow. Building codes generally allow attic vent screening as long as the mesh size is greater than 1.5875mm.

32.2.5 Interior walls

32.2.5.1 Construct interior walls to minimize harborage and pathways for insect and rodent pests

1. Baseboard installation.
   A. Use straight base rather than cove base. Cove bases are typically installed with adhesives that may be food for cockroaches, and the gap behind the cove provides potential harborage for a variety of pests, including bed bugs. Alternately, use cove bases that have no gap, and install them to be more easily removable (using screws or nails) to make inspection and treatment easier.
2. Gaps between wall and flooring.
   A. In an interior wall made of wood and drywall, the bottom plate is not usually completely tight against the floor due to uneven floors and the natural bends in wood. Similarly, the drywall panels that are hung on the wall framing often have a gap along the bottom edge. Gaps should be minimized as much as possible during construction.

32.2.6 Floors

32.2.6.1 Floors should be durable, non-absorbent, without crevices, and capable of being effectively cleaned

1. Concrete.
   A. Concrete floors should be durable, steel-float finished and sealed to prevent dirt accumulation in crevices and provide a non-slip surface.
2. Carpet.
   A. Avoid installing carpet in areas prone to moisture: bathrooms, laundry rooms, kitchens, entryways and damp basements. Moisture promotes fungal growth and accompanying insect infestations.

32.2.6.2 Floors should be durable, non-absorbent, without crevices, and capable of being effectively cleaned

1. Moisture resistant materials in commercial kitchens.
   A. In commercial food preparation areas, use quarry tile, poured seamless epoxy floor, approved commercial grade vinyl, or similar materials to avoid moisture accumulation and harborage of insect pests.

32.2.6.3 Design floor drains for complete drainage and easy cleaning

1. Floor slope.
   A. Where floor drains are installed, slope surrounding floors 0.635cm per 0.3048m to the drain.
2. Drain covers and baskets.
   A. Cover floor drains with mesh screen covers or sunken drain baskets. Baskets or covers should be removable for cleaning. Codes usually require removable strainers.
3. Floor drain access.
   A. Floor drains should be easily accessible to enable cleaning and inspection. Floor drains should not be located under fixed kitchen equipment.

32.2.7 Doors

32.2.7.1 Reduce pest access through doors.

1. Solid-core doors.
   A. Use solid-core doors where possible. Solid-core doors are more durable and do not have hidden recessed areas or cavities that could harbor pests.
2. Doors with metal kick plates.

   A. In areas of high rodent pressure, fit external doors with 26-gauge sheet metal kick plates 30.48cm tall and mounted no more than 0.635cm from the bottom of the door. Metal plates should not interfere with the swinging of the door.
3. Thresholds of exterior doors.
   A. Doors should fit tightly; the distance between the bottom of the door and the threshold should not exceed 0.635cm. Use tight-fitting door sweeps if gaps are larger than 0.635cm. If appropriate, use automatic door sweeps, which drop to seal against the floor when the door is closed. If automatic sweeps are not possible, bristle sweeps are preferable to rubber or plastic. If rodent pressure is high, protect rubber and plastic sweeps with metal kick plates installed on the outside of the door.
4. Air curtains.
   A. In commercial buildings, specify air curtains (air doors) where doors are frequently open. Use models that start automatically when the door is opened to conserve energy. Properly installed and sized air curtains are typically about 80% effective in preventing insect entrance. Users have reported over 99% reduction in fly numbers.
5. Self-closing doors.
   A. All doors leading to the outside should be equipped with self-closing devices and supplementary screen doors. For large overhead doors, such as warehouses or processing facilities, consider electrically operated screen doors or a permanent frame with screening. As appropriate, make sure the closure mechanisms are safe for children and the elderly. Follow manufacturer's safety instructions for closure mechanisms.
6. Screen doors.
   A. Use screen doors with durable frames to prevent warping and ensure a good seal from the outdoors.
7. Weather-stripping of exterior doors.
   A. Use weather-stripping of all exterior doors to better seal against pest entry.

32.2.8 Windows

32.2.8.1 Design and construct windows to minimize pest attraction and access to interior

1. Window ledges.
   A. Slope smooth-surfaced window ledges and projections at 45 degrees to minimize bird perching and roosting.
2. Screens.
   A. International Property Maintenance Code requires screens on windows in habitable rooms as well as rooms used for food storage and preparation unless air curtains or fans are employed.
3. Weather-stripping.
   A. Use weather-stripping for all operable windows.

32.2.9 Bedrooms

32.2.9.1 Minimize bed bug harborage

1. Moldings and joints.
   A. Moldings and joints around the room perimeter (floor, doors, cabinets, and windows) should be caulked with silicone sealant to eliminate hiding spots for bed bugs.
2. Hard flooring materials.
   A. Use wood, tile, linoleum, or similar flooring materials instead of carpets or rugs.
3. Built-in furniture.
   A. Built-in furniture provides harborage for bedbugs that is difficult to inspect. If built-in furniture is used, provide access for inspection.
4. Furniture that minimizes attractiveness to bedbugs.
   A. Use leather, metal, plastic or laminate furniture rather than upholstered, wicker, or wood furniture. Metal and laminate furniture is harder for bedbugs to climb than wood furniture. If upholstered furniture is used, it should have metal legs and the fabric should be at least a few inches from the floor and from any other pieces of furniture. If possible, use furniture that is easily washable and light colored. Beds should not have headboards and mattresses should be encased in commercially available, insect-proof coverings.

32.2.9.2 Seal openings that allow bedbug movement between rooms or units

1. Openings in floors, walls, and ceilings.
   A. Openings around pipes or other structures that come through walls, floors and ceilings should be sealed. caulk, foam, seal, paint, or otherwise fill any cracks and holes larger than the thickness of a credit card.

32.2.10 Bathrooms

32.2.10.1 Prevent moisture accumulation in bathrooms

1. Floor, wall, and ceiling penetrations.
   A. All penetrations of floors, walls, and ceilings

should be sealed with metal escutcheon plates if feasible, or with polyurethane foam, silicone sealant, or other flexible sealant. Penetrations include electrical wires, supply and drain pipes, heating and ventilation systems, and recessed lights. Larger gaps may require the addition of copper or stainless steel wool to the foam, in order to effectively bar access to rodents.

2. One-piece countertops.
   A. Countertops should be one piece if possible, that is, with an attached backsplash. If this is not feasible, use an elastomeric sealant to seal along edges of countertops and backsplashes where they meet walls.
3. One-piece tub or shower enclosures.
   A. Use one-piece tub or shower enclosures where they are appropriate with the bathroom design, to minimize potential infiltration of moisture.
4. Water controls
   A. In large shower enclosures, offset water controls so that they are close to the door. This makes them easier to use,and lessens the likelihood of water escaping the shower.
5. Shower shelves and soap holders.
   A. Slope horizontal surfaces of soap holders, shampoo cubbies, and shower seats so water drains into the shower or tub. This reduces moisture buildup.
6. Toilet tanks.
   A. Use insulated toilet tanks to minimize toilet sweating and moisture buildup.
7. Slope ventilation ducts.
   A. Ensure horizontal ventilation ducts are sloped so that condensation water doesn't accumulate in the ducts.
8. Bathroom fans with a humidistat.
   A. Install bathroom fans with a humidistat to more effectively avoid moisture buildup. Humidistats automatically turn on fans when humidity reaches a certain level.

32.2.11 Kitchens: general

32.2.11.1 Design kitchens for easy cleanability and pest inspections

1. Joints between toe-kicks and floor.
   A. Use curved joints between floor and the vertical toe-kick under cabinets rather than right angle joints. "Roll" the edge of the floor up to the toe-kick with a smooth curve. Ensure that edges are properly sealed to avoid creating harborages for pests.
2. Joints between sinks and countertops.
   A. Avoid joints that are difficult to clean between sinks and countertops. Use undermount or integral sinks.
3. Kitchen cabinets with smooth, flat doors.
   A. Specify cabinets with flat rather than raised panel doors. Raised panels or elaborate moldings create more opportunities for dirt accumulation. Enamel, gloss paint, or other smooth finishes are preferable to make cleaning easier.

32.2.11.2 Eliminate moisture buildup in kitchens.

1. One-piece countertops.
   A. Use one piece countertops with attached backsplash when possible. If one-piece countertops are not feasible, use an elastomeric sealant to seal along edges of countertops and backsplashes where they meet walls.

32.2.11.3 Eliminate potential pest harborage

1. Cabinets contacting floor and walls.
   A. Using an elastomeric sealant, seal joints where cabinets contact the floor and walls. The wall behind the cabinet should be free of holes or voids. The goal is to prevent access to hidden spaces favored by cockroaches. This is especially critical in institutional kitchens.

32.2.12 Kitchens: institutional

32.2.12.1 Design kitchens for easy cleanability and pest inspections

1. Food storage areas.
   A. Food storage should be elevated off the floor and away from walls to facilitate inspection and cleaning.
2. Coved junctions.
   A. Wall-wall and wall-floor junctions should be coved to facilitate easier cleaning and prevent the accumulation of debris. Wall-ceiling junctions should be coved or sealed. Rubber or flexible plastic baseboard coving should be avoided, since it is very difficult to remove and inspect. Avoid cove base that is installed with adhesive. Choose coving that does not include an air gap under the curve, which could provide harborage for cockroaches.
3. Lighting in storage areas.
   A. Storage areas should have adequate lighting to allow efficient cleaning and easy pest inspection.
4. Access to suspended ceilings.
   A. Provide access to voids above suspended ceilings for inspections and cleaning. In large buildings, provide walkways for this purpose.
5. Cabinets with legs.

   A. Specify cabinets with legs to facilitate cleaning underneath. Legs should either be bolted to the floor with gaskets or sealant to eliminate gaps, or should be on wheels to enable easy moving.
6. Wheeled appliances.
   A. Specify the use of wheeled stoves, mixers, refrigerators, and other appliances to encourage regular cleaning. Wheel fenders should include adequate clearance for cleaning around the wheels.
7. Drains.
   A. Locate drains so that they are accessible for cleaning.
8. Flush thresholds in doorways.
   A. When possible use flush thresholds in doorways. Thresholds collect dirt and food debris that can attract fruit flies or roaches.
9. Food preparation areas.
   A. When possible, locate food preparation areas on islands rather than against walls. Cleanup is generally easier around islands.
10. Stainless steel backsplashes.
   A. Install stainless steel backsplashes behind sinks and work surfaces for easier cleaning and avoid moisture buildup. Use sealant around edges.

32.2.12.2 Eliminate moisture buildup in kitchens

1. Ventilation in moist areas.
   A. Provide extra ventilation for dishwasher, cooking line, and in the mop room. This can be accomplished through modifications of venting or through installation of small fans. Reduction of moisture buildup will inhibit fruit flies and other pests.

32.2.12.3 Minimize pest entrance into kitchen

1. Separation of refuse disposal, recycling areas, and food delivery entrances.
   A. Refuse disposal, recycling areas, and food delivery entrances should ideally be located away from frequently used entries. Refuse disposal and recycling areas attract flies and other pests, even when bins are well sealed and frequently cleaned. If the disposal area is adjacent to frequently used entries, such as those used for food deliveries, it is easier for the flies to enter the kitchen.
2. Self-closing doors for food storage rooms.
   A. Use self-closing doors for food storage rooms to shut out rodents and some insect pests. Doors should be adequately sealed around the edges, with door sweeps or bottoms and no gaps over 0.635cm.
3. Wiring and pipe penetrations.
   A. Seal all penetrations through walls and floors, including wiring and pipe penetrations through wall framing at top and bottom plates. Use either an elastomeric sealant or fire block, depending on the size of the gap, its location, and local building codes. This is especially important in institutional kitchens where there is no tolerance for pest infestations. For larger gaps, including copper or stainless steel wool with foam may be necessary to exclude rodents.

32.2.12.4 Eliminate potential pest harborage

1. Wall hangings and signs.
   A. Any wall storage, ornamentation, signage, bulletin boards, etc. should be sealed using elastomeric sealant or hung at least 0.635cm from the wall to discourage pest harborage.
2. Storage rooms without void spaces.
   A. If rodent pressure is high, design food storage rooms without double walls, false ceilings, enclosed staircases, boxed plumbing, and voids under cabinets. This permits easy inspection and removes harborage.
3. Ceramic outside corner tiles.
   A. Avoid use of ceramic outside corner tiles. Ceramic tiles located in heavily used areas are highly prone to breakage. Broken tiles provide access to voids that can harbor pest insects. Durable outside corners, such as metal or plastic, are preferred alternatives.

32.2.13 Utilities, HVACs, chutes

32.2.13.1 Design and construct utility penetrations, such as water pipes, electrical wires and conduit, cold air return ducts on forced air furnaces, and exhaust vents, to minimize pest intrusions

1. Rodent-resistant materials to seal around utility penetrations.
   A. Use escutcheons, cement mortar, or copper mesh or hardware cloth embedded in patching plaster to seal any openings around utility penetrations.
2. Use sealant on small gaps around penetrations.
   A. Where rodent pressure is not high, or with gaps < 6.35mm, use silicone sealant to seal around utility penetrations to deter insect movement.
3. Air intakes and vents.
   A. Outside air intakes or vents for wall-mounted heaters, air conditioners, and exhaust fans should be screened to exclude insects a variety of pests. Use 10-mesh screen or smaller and design/install the screen so that it can be easily

removed for cleaning.

4. Outlets and switches.
   A. Use foam gaskets behind electrical cover plates to seal off access to pests, particularly in pest sensitive areas such as institutional kitchens.
5. Cleaning around utility penetrations.
   A. There should be adequate space and access for cleaning around utility penetrations.
6. Dryer exhaust vents.
   A. Terminal ends for clothing dryer vents are available that exhaust the air vertically rather than horizontally and may be more effective in excluding rodents than the usual flapper-type vent ends.

32.2.13.2 Design trash and laundry shafts to exclude pests and minimize pest harborage.

1. Chute doors.
   A. Trash and laundry chutes should have tight-fitting doors. Avoid any gaps between door and surrounding wall.
2. Chutes circular in cross section.
   A. Use metal garbage and laundry chutes with a circular cross section to avoid accumulation of debris in hard-to-clean corners.
3. Trash chute size.
   A. Hopper doors into vertical trash chutes should be large enough to fit a full trash bag, to avoid the accumulation of debris from torn bags and keep chutes cleaner.

32.2.14 Refuse and recycling

32.2.14.1 Exclude rodents from refuse and recycling areas

1. Prevent access to refuse and recycling areas.
   A. Design refuse and recycling areas with concrete pads that extend past the boundaries of the enclosure so that rodents cannot burrow into the enclosed area.
2. Rodent-resistant enclosures.
   A. Enclose refuse and recycling areas with metal, concrete, or similar materials to prevent vertebrates from gnawing or climbing the enclosure. Enclosures should be solid and extend all the way to the ground. Do not plant ivy around enclosures.
3. Pest-resistant containers.
4. Use refuse containers that are heavy duty, rust resistant, rat and damage resistant, and equipped with tight-fitting lids. Racks or stands prevent corrosion or rusting of containers, reduce rat shelter under containers, and minimize the chance of containers being overturned.

32.2.14.2 Design refuse and recycling areas for easy cleaning

1. Floors areas.
   A. Use concrete floors in refuse and recycling areas
2. Drainage.
   A. Slope floor of recycling and refuse area to a drain connected to the sanitary sewer.
3. Hose bib.
   A. Provide a hose bib near the enclosure for periodic cleaning.

32.2.14.3 Durable pest-resistant construction materials

1. Termite resistant building materials
   A. Termite-resistant materials include brick, concrete, stone, naturally resistant wood, metal, and rigid plastics. Naturally resistant woods commonly used in North America include: western red cedar, redwood, incense cedar, Port Orford cedar, black locust, northern white cedar, and Alaska cedar are known to dissuade termite infestations. Using these durable woods makes infestation less likely but does not guarantee that infestations will not occur. It is also important to note that only the heartwood from these species is resistant. While they do not constitute a food source for wood-destroying insects, brick, concrete block, and plastic may still provide harborage for the pests. Foam insulation mounted on the outside of foundations, for example, provides near-ideal temperature and humidity conditions for termite tunnels. Regular termite inspections are important even when using resistant materials.
2. Rodent resistant building materials.
   A. Rodent teeth are well adapted to gnawing through all but the hardest materials. Rats have been known to gnaw through lead. Rodent-resistant materials include concrete with a minimum thickness of 5.1cm if reinforced, or 9.5 cm if not reinforced; galvanized sheet metal if 24 gauge or heavier for wall or pipe barriers, 22-gauge or heavier for kick plates or door edging, or 14-gauge if perforated or expanded sheet metal grills; brick if 9.5 cm thick with joints filled with mortar; hardware cloth (wire mesh) if woven, 19- gauge, 1.3cm x 1.3cm mesh to exclude rats or 24-gauge, 0.6cm x 0.6cm mesh to exclude mice; aluminum if 22-gauge for frames and flashing or 18-gauge for kick plates and guards; plaster; or corrugated metal.

32.2.15 General area

32.2.15.1 Design for easy inspection

1. Minimize inaccessible spaces.
    A. Example of inaccessible spaces include: false ceilings, false bottoms under cabinets, pegboard storage systems, air plenums, gaps behind or within machinery, spaces behind coved baseboards, or enclosed spaces under bathtubs.
2. Access to enclosed spaces.
    A. Where hard-to-access spaces are necessary, provide enough access to allow inspections of the space. Examples include: 1) Provide hatches or walkways for inspection of voids above suspended ceilings, 2) leave 15.24cm clearance between wood structures and soil (preferably 18 inches in areas with high termite pressure), and 3) make sure expansion joints or utility breaks in foundation are accessible to inspection. Note that access to attics, crawl spaces, and other underfloor spaces is required by code.

33 Air movement optimization design

A.k.a., Wind movement optimization design.

Atmospheric movement may be calculated for both the interior of a building a between buildings in a habitat. In some climates, it is preferable to have more airflow between buildings (e.g., hot and humid climates), and in others it is preferred to have less (e.g., cold climates).
In some interior areas, it is preferable to have more air flow, less air flow, and/or the ability to customize the airflow. The airflows within and between buildings can be simulated with real-world data.

34 Local wildlife population interaction optimization

All architecture will interact to some degree with the local wildlife. Wild species interaction reviews may be done on architecture. The most common form of interaction between wildlife and architecture is with birds. Birds poop on architecture and can fly into ("strike") glass. It is possible to reduce bird strikes when glass is present via a number of different methods:

1. Stickers on the glass (is often sufficient).
2. Tapped line spacing.
3. Screens (including exterior placed zen curtains) and shutters.
4. Sun shades over windows and awnings.
5. Covering the glass on the outside with netting at least 3 inches from the glass, taut enough to bounce birds off before they hit the glass.
6. Lights ought to be oriented toward the ground to not attract or disorient migrating birds.

35 Modularity design optimization

A.k.a., Modularity engineering.

Modular architectural structures are built in large three-dimensional sections, which are typically 95% complete when they leave the structural production center. The modules are then transported to the site and placed (often by crane) onto a permanent foundation where final assembly is complete.

35.1 Modularity analysis

A modularity analysis involves:

1. Structural analysis.
2. Connectivity analysis.
3. Fixtures analysis.
4. Fitting analysis.
5. Internal area module analysis.

36 Clothing Service System

Read: As part of the architectural service system.

Clothing characteristics include:

1. Type of fabric.
2. Wash and care instructions.
3. Source of fiber (natural or synthetic, or mix).

Terms used to describe clothing production include:

1. **Textile production (industry):** concerned with the design, production, and distribution of fiber, yarn, cloth, and eventually, clothing or some other technical textile usage.
2. **Technical textiles used by humans and machines:** including clothing, furnishings for living (upholstery, curtains, draperies, carpets, towels), bedding, agro-textiles (i.e., textiles used in cultivation), geo-textiles (i.e., textiles used for infrastructure), transporation vehicle textiles, medical textiles, and machine textiles (conveyer, rope, filtration, etc.).
3. **Fiber (fibre):** thin thread of natural or synthetic material that can be used to make yarn. A material which is available in the form of thin and continuous strand is called fibre.
4. **Natural fiber:** fiber from a natural source, such as a plant or animal, that can be used to make yarn without chemical alteration.
5. **Synthetic fiber:** fiber that is man-made; the original substance is chemically altered to form fiber that can be used to make yarn.
   A. Made from cellulose - cellulose based products (e.g., rayon and acetate).
   B. Made from hydrocarbon - hydrocarbon based products (petroleum-based fabrics include Kevlar®, nylon, polyester, acrylic, polypropylene, olefin, and spandex).
6. **Yarn:** a long continuous length of interlocked fibres (Read: fibers twisted together) which is suitable for using in the production of products (e.g., textiles, sewing, crocheting, knitting, weaving, embroidery and rope making). Yarn is produced from fiber. A pulled and twisted strand of fibre used to make fibre is called as yarn.
7. **Fabric:** a network of single or multiple yarns. Fabrics are made up of yarns and yarn is made up of fibres. Fabric is the pre-production state of a finished product. Could be considered synonymous with "cloth".
8. **Warp:** the set of lengthwise threads on a loom that are crossed at right angles by the weft.
9. **Weft:** thread or yarn which is drawn through the warp to create cloth.
10. **Cloth:** is a kind of fabric that consists of a fine, flexible network of yarns. It is what the finished product is made of. Could be considered synonymous with "fabric".
11. **Clothing:** is what people wear.

36.1 Fabric modification processes

Common processes that happen to fabric include, but are not limited to:

1. Bleaching.
2. Optical whitening.
3. Branching.
4. Sanforization.
5. Calendaring.
6. Scorching or gassing.
7. Desizing.
8. Purging.
9. Sanding.

36.2 Clothing object identification

A.k.a., Clothing labels.

Clothing labels provide information on what the fabric is made from and where the clothing was made.

36.3 Fiber biodegradability

Biodegradable means that a material will break down or decompose through microbial (and other) action into basic elements found in nature. Many materials over time will degrade from sunlight (UV), heat, moisture and mechanical stress, but this alone is not biodegradation. Compostable is the idea of biodegredation, where materials will break down quickly into nutrient-rich soil.

Natural fibres are biodegradable, but synthetic fibres (made by chemical machines) are recalcitrant to biodegradation and need long periods of time giving pollutant products the time to breakdown. Certain studies have found the synthetic material to be an endocrine disruptor that can potentially effect fertility. Organic fibres will biodegrade easily and into "environmentally friendly" products; while synthetic fibres will leave residual particles (sometimes even plastic) in the environment for long periods of time.

36.3.1 Fiber decomposition

Natural fibres and synthetic fibres can be torn apart by tearing machines to shorter lengths. These fibers can then be mixed to produce new textiles. For every kg of virgin cotton displaced by second-hand clothing approximately electrical and machine power is saved, and for every kilogram of polyester electrical machine power is saved. Synthetic fibres are somewhat recycleable through the process of melting the polymer followed by fibre production from extruder. Natural fibres are not convenient to melt since they have no melting properties.

36.4 Clothing dis-ease induction

There are forms of clothing that can be worn that restrict movement and can cause physiological issues in the wearer over time. For example,

1. Shoes can prevent their wearer from walking optimally, and often, over time, lead to foot pain and deformation. Shoes that are too tight can easily cause bunions (a deformation of the knuckle of the big toe). Shoes that are higher in the back than in the front can lead to shortening of the calf musculature.
2. Clothing around the waste can be too tight, causing digestive and other problems.
3. Clothing with toxic chemicals can lead to human skin absorbing excessive amounts of otherwise avoidable toxins.

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Table 10. *Table showing BIM related level of development (LOD) stages in relation to model content.*

Model Content	LOD 100	LOD 200	LOD 300	LOD 400	LOD 500
3D Model-based Coordination	Site level coordination	Major large object coordination	General object-level coordination	Design certainty coordination	N/A
4D Scheduling	Total project construction duration. Phasing of major elements	Time-scaled, ordered appearance of major activities	Time-scaled, ordered appearance of detailed assemblies	Fabrication and assembly detail including construction means and methods (cranes, man-lifts, shoring, etc.)	N/A
Cost Estimation	Conceptual cost allowance Example $/sf of floor area, $/hospital bed, $/parking stall, etc. assumptions on future content	Estimated cost based on measurement of the generic element (i.e. generic interior wall)	Estimated cost based on measurement of specific assembly (i.e. specific wall type)	Committed purchase price of specific assembly at buyout	Record cost
Program Compliance	Compliance Gross departmental areas	Specific room requirements	FF & ampE, casework, utility connections	Specific manufacturer selections	Purchase documentation
Sustainable Materials	LEED strategies	Approximate quantities of materials by LEED categories	Precise quantities of materials with percentages of recycled and/or locally purchased materials	Precise simulation based on the specific manufacturer and detailed system components	Commissioning and recording of measured performance
Analysis/ Simulation	Strategy and performance criteria based on volumes and areas	Conceptual design based on geometry and assumed system types	Approximate simulation based on specific building assemblies and engineered systems	Precise simulation based on the specific manufacturer and detailed system components	

Table 11. *Simplified materials construction technology table (materials technology construction matrix).*

	Materials	Calculations	Outcomes
Technologies			
Calculations			
Outcomes			

Table 12. *Design build matrix.*

Build	Design				
	Schematic	Design Development	Contract Documents	Bid / Negotiations	Construction Observation
Site					
Foundation					
Framing					
Roofing					
Exterior Finish					
Plumbing					
HVAC					
Electrical					
Insulation					
Walls					
Interior Finish					
Landscape					

TABLES

Table 13. *Table shows maximum gap sizes for excluding various pests. (Geiger, 15, 2012)*

Animal Type	Common Name	Scientific Name	Maximum opening size / mesh size	Reference
Insects / arthropods	Biting midges	Ceratopogonidae	0.605 mm ~30 mesh	AFPMB, 2009
	Cheese skipper	Piophila casei	0.595 mm ~32 mesh	Ebeling, 1975*
	Cockroaches	Blatella germanica	1.66 mm ~12 mesh	Koehler, 1994**
	Cotton aphid	Aphis gossypii	0.341 mm ~50 mesh	Bethke & Paine, 1991*
	Fruit flies	Drosophilida spp.	2.12 mm ~10 mesh	NPS, 2006
	Honeybees	Apis spp	3.00 mm ~7 mesh	NPS, 2006
	House flies	Musca domestica	2.03 mm ~10 mesh	Block, 1946
	Mosquito	Aedes egyptii	1.03 mm ~18 mesh	Wesley & Morrill, 1956; Block, 1946
	Mosquito	Anopheles quadrimaculatus, Culex quinquefasciatus	1.38 mm ~14 mesh	Block, 1946
	Redlegged ham beetle	Necrobia rufipes	0.595 mm ~32 mesh	Ebeling, 1975*
	Sand flies	Phlebotominae spp. (Psychodidae)	0.605 mm ~30 mesh	AFPMB, 2009
	Termites (Eastern subterranean)	Reticulitermes flavipes	0.610 mm ~30 mesh	Tucker, 2008*
	Termites (Formosan	Coptotermes formosanus	0.660 mm ~28 mesh	Grace et al, 1996*
	Thrips	Frankiniella occidentalis	0.192 mm ~80 mesh	Bethke & Paine, 1991*
	Yellowjackets	Vespidae spp.	3.00 mm ~7 mesh	NPS, 2006
	Scorpions	Scorpionida spp	1.6 mm	Timm & Marsh, 1997
Birds	Pigeons	Columba livia	50.8 mm (2 in)	Timm & Marsh, 1997
	Sparrows, Starlings	Passer spp., Sturnus vulgaris	19.1 mm (0.75 in)	Timm & Marsh, 1997
Mammals	Bats	Chiroptera spp	6 mm/0.25 in	Greenhall & Frantz, 1994
	Mice	Mus musculus	6 mm/0.25 in	Greenhall & Frantz, 1994
	Rats	Rattus norvegicus, R. rattus	9.5mm/3/8 in gaps under doors; 18 gauge 13 mm/0.5 in mesh	Corrigan, 1997
	* Studies marked with an asterisk identified nominal gap sizes; these were matched with the closest Tyler mesh size. All other studies referred specifically to minimum mesh sizes; these were matched with approximate gaps sizes. Mesh opening sizes are nominal, i.e., not diagonal.			
	**Study pertained to preferred harborage for nymphs, not minimum opening for access, which is likely smaller.			

TABLES

Table 14. *List of common building materials.*

Adhesives	Coal ash	Gypsum.
Adobe.	Concrete	Hempcrete
Acrylic.	Concrete fibre	High alumina cement
Aggregate	Copper.	Icynene spray foam insulation
Alkali-activated binder	Daub	Laminated veneer lumber LVL
Aluminium.	ETFE	Lead in construction
Architectural fabrics	Fibre cement	Limecrete
Asphalt	Glass for buildings	Masonry
Bulk filling materials	Glass reinforced concrete	Mastic sealant
Carbon fibre	Glass reinforced plastic GRP	Metal
Cast iron	Glulam	Mortar
Cavity wall insulation	Graphene in civil engineering	Mycelium
Cement	Gravel	Nylon
Ceramics	Gravel v hardcore v aggregates.	Oil - a global perspective
Chert	Grouting in civil engineering.	Paint
Clay		

Table 15. *Comparison of BIM work stages.*

PAS 1192 Process map	APM (listed in CIC BIM protocol)	RIBA 2013	CIC BIM protocol (attributed to PAS 1192)
1 Brief	0 Strategy	0 Strategic definition	1 Brief
	1 Brief	1 Preparation and brief	
2 Concept	2 Concept	2 Concept design	2 Concept
3 Definition	3 Definition	3 Developed design	2 Development design
4 Design	4 Design (production information)	4 Technical design (Procurement is flexible and does not have a numbered stage)	4 Production
5 Build & Commission	5 Build & Commission	5 Construction (including mobilization)	5 Installation
6 Handover & Closeout	6 Handover & Closeout	6 Handover & Closeout	6 As constructed
7 Operation In use (no number)	7 Operation and end of life	7 In use	7 In use

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Table 16. *Method of calculating coincident peak demand.*

Description	Total connected load, kw	Demand factor, %	Maximum demand, %	Load factor, %	Coincidence factor, %	Coincidence peak, kw
Fire station	14.6	30	4.4	15	521	2.3
X technology	#	#	#	#	#	#
Y technology	#	#	#	#	#	#
Z technology	#	#	#	#	#	#
					Total	
					System losses	
					Grand total	

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Table 17. *UniFormat for universal preliminary planning. This list of plannable elements contains numbers and titles associated with phases and/or deliverables. This list may be compared against other "Title and Numbering" standards, including but not limited to: CSI MasterFormat, etc. (Guthrie, 2010)*

Number	Title
1	**ELEMENT: PROJECT COORDINATION (CSI, PROJECT DESCRIPTION)**
10	**Project description**
1010	Project summary
1020	Project program
1030	Existing conditions
1040	Owner's work
1050	Funding
20	**Proposal, bidding, and contracting**
2010	Delivery method
2020	Qualification requirements
2030	Proposal requirements
2040	Bid requirements
2050	Contracting requirements
30	**Cost summary**
3010	Elemental cost estimate
3020	Assumptions and qualifications
3030	Allowances
3040	Alternatives
3050	Unit prices
A	**ELEMENT: SUBSTRUCTURE (CSI - A, SUBSTRUCTURE)**
A10	**Foundations**
A1010	Standard foundations
A1020	Special foundations
A1030	Slab on grade
A20	**Basement construction**
A2010	Basement excavation
A2020	Basement walls
B	**ELEMENT: SHELL (CSI - B, SHELL)**
B10	**Superstructure**
B1010	Floor construction
B1020	Roof construction
B20	Exterior enclosure
B2010	Exterior walls
B2030	Exterior windows
B30	**Roofing**
B3010	Roof coverings
B3020	Roof openings
C	**ELEMENT: INTERIOR SURFACES (CSI - C, INTERIORS)**
C10	**Interior construction**
C1010	11 Partitions and partitioned modules
C1020	12 Interior doors
C1030	13 Fittings
C20	**Stairs**
C2010	Stair construction
C2020	Stair finishes
C30	**Interior finishes**
C3010	Wall finishes
C3020	Floor finishes
C3030	Ceiling finishes
D	**ELEMENT: UTILITY SERVICES (CSI - D, SERVICES)**
D10	**Conveying**
D1010	Elevators and lifts
D1020	Escalators and moving walks
D1090	Other conveying systems
D20	Plumbing
D2010	Plumbing fixtures
D2020	Domestic water distribution
D2030	Sanitary waste
D2040	Rain water drainage
D2090	Other plumbing systems
D30	**Heating, ventilation, and air conditioning (HVAC)**
D3010	Energy supply
D3020	Heat generation
D3030	Refrigeration
D3040	HVAC distribution
D3050	Terminal and packaged units
D3060	HVAC Instrumentation and controls
D3070	Testing, adjusting, and balancing
D3090	Other special HVAC system and equipment
D40	**Fire protection**
D4010	Sprinklers
D4020	Standpipes
D4030	Fire protection specialists

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D4090	Other fire protection systems
D50	**Electrical**
D5010	Electrical service and distribution
D5020	Lighting and branch wiring
D5030	Communications and security
D5090	Other electrical systems
D60	**Basic materials and methods**
E	**ELEMENT: EQUIPMENT AND FURNISHINGS (CSI - E, EQUIPMENT AND FURNISHINGS)**
E10	**Equipment**
E1010	Commercial equipment
E1020	Institutional equipment
E1030	Vehicular equipment
E1090	Other equipment
E20	**Furnishings**
E2010	Fixed furnishings
E2020	Movable furnishings
F	**ELEMENT: SPECIAL CONSTRUCTION AND DEMOLITION (CSI - F, SPECIAL CONSTRUCTION AND DEMOLITION)**
F10	**Special construction**
F1010	Special structures
F1020	Integrated construction
F1030	Special construction systems
F1040	Special facilities
F1050	Special controls and instrumentation
F20	**Selective demolition**
F2010	Building elements demolition
F2020	Hazardous components abatement
G	**ELEMENT: BUILDING SITEWORK (CSI - G, BUILDING SITEWORK)**
G10	**Site preparation**
G1010	Site clearing
G1020	Site demolition and relocation
G1030	Site earthwork
G1040	Hazardous waste removal
G20	**Site improvements**
G2010	Roadways
G2020	Parking lots/garages
G2030	Pedestrian paving
G2040	Site development
G2050	Landscaping
G30	**Site civil/mechanical utilities**
G3010	Water supply
G3020	Sanitary sewer
G3030	Storm sewer
G3040	Heating distribution

G3050	Cooling distribution
G3060	Fuel distribution
G3090	Other site mechanical utilities
G40	**Site electrical utilities**
G4010	Electrical distribution
G4020	Site lighting
G4030	Site communications and security
G4090	Other site electrical utilities
G90	**Other site construction**
G9010	Service tunnels
G9090	Other site systems
Z	**ELEMENT: GENERAL (CSI - Z, GENERAL)**
Z10	**General requirements**
Z1010	Administration
Z1020	Quality requirements
Z1030	Temporary facilities
Z104	Project closeout
Z1050	Permits, insurance, and bonds
Z1060	Fees
Z20	**Contingencies**
Z2010	Design contingency
Z2020	Escalation contingency
Z2030	Construction contingency

Life Support: Water Service System

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Abstract

Water is one of the most important elements humankind needs to survive. It is a universal solvent for living things, which can dissolve many substances, both solid and gaseous, that come into contact with it. Humans use water everywhere, constantly. Water is called the "universal solvent" because it is capable of dissolving more substances than any other liquid. This is important to every living thing on earth. Water is a core component of the planet's ecospheric cycle. Hydrology is the study of water in its totality, including is cycles and qualities. Water is an essential requirement of all life. Water is a uniquely accountable physical resource (Read: object). Different needs, and sub-services therein, have different requirements of and for water. Water is a material with many different sub-compositions, some of which are usable for specific functions, and others of which are not. Water serves many functions in a materialized societal system. The the processing and distribution of water can be integrated into a city platform.

Graphical Abstract

Image Not Yet
Associated

1 Hydrological cycle

A.k.a., Water cycle.

Hydrology is the scientific study of the movement, distribution, and quality of water on Earth and other planets, including the hydrologic cycle, water resources and environmental watershed sustainability. A watershed is the source, stock, and flow of water withing a geographical region on the planet. Watersheds typically define a bio-region. Hydrology is subdivided into surface water hydrology, groundwater hydrology (hydrogeology), and marine hydrology. Domains of hydrology include hydrometeorology, surface hydrology, hydrogeology, drainage basin management and water quality, where water plays the central role. In terms of environmental measurements, hydrology refers to the physical movement of a body of water, including changes in water level, flow, and other dynamic processes. Hydrological modeling refers to modeling of the hydrologic cycle (i.e., water cycle). The water cycle, also known as the hydrologic cycle or the H2O cycle, describes the continuous movement of water on, above and below the surface of the Earth. The hydrologic cycle is the term used to describe the natural circulation of "raw" water in, on, and above the earth. Water occurs in many forms as it moves through this cycle. The land area through which water naturally flows is called a watershed.

Water is placed in the air by evaporation from water and land surfaces and by transpiration from plants. It then condenses to produce cloud formations and returns to earth as rain, snow, sleet, or hail. Some of this evaporates, while some flows as runoff into lakes and streams. The remainder goes into the soil and then into underlying rock formations by seepage or infiltration. The water which has seeped through the earth will finally find its way to the surface through springs. It can also flow through porous media until intercepted by streams, lakes, or oceans. The cycle does not always progress through a regular sequence; steps may be omitted or repeated at any point. For example, precipitation in hot climate may be almost wholly evaporated and returned to the atmosphere.

NOTE: *With the appropriate technology, water may be collected at any point in the Earth's water/hydrological cycle.*

The mass of water on Earth remains fairly constant over time but the partitioning of the water into the major reservoirs of ice, fresh water, saline water and atmospheric water is variable depending on a wide range of climatic variables. The water moves from one reservoir to another, such as from river to ocean, or from the ocean to the atmosphere, by the physical processes of evaporation, condensation, precipitation, infiltration, runoff, and subsurface flow. In doing so, the water goes through different phases: liquid, solid (ice), and gas (vapor). The water cycle involves the exchange of energy, which leads to temperature changes. For instance, when water evaporates, it takes up energy from its surroundings and cools the environment. When it condenses, it releases energy and warms the environment. These heat exchanges influence climate.

On earth, water moves continuously through the water cycle which comprises (the primary motions of):

1. Evaporation and transpiration (from landscape).
2. Condensation (in atmosphere).
3. Precipitation (onto landscape).
4. Run-off (off landscape).
5. Infiltration (into landscape).

2 Water service system design

The water system is a system of engineered hydrologic and hydraulic components that provide a water supply, modified where necessary, to meet service requirements.

A water system has the basic functional (process) hookups to the larger ecological and local tactical habitat systems:

1. **Water collection and storage** (from natural ground and atmospheric systems).
2. **Water processing** (within the habitat to meed production and end-user requirements).
3. **Water re-cycling and re-use** (within the network, as necessary and appropriate).
4. **Water directing within the network** (as necessary and appropriate).

A water supply system involves everything from the collection of source water through to the point of use, as well as all transformation, recycling, and transportation therein.

Water-type functional spaces and activities include, but may not be limited to:

1. Water acquisition centers (i.e., plants, arrays).
2. Water processing/transformation centers.
3. Water transfer pathways.
4. Water technology production and cycling centers.
5. Computational, architectural, and power systems are required.

A water supply system typically includes:

1. An **ecosystem** that re-cycles water and fulfills the H20 needs of organisms living in a habitat. The ecosystem of a water body is known as an 'aquatic ecosystem'.
2. A **drainage basin** (**catchment basin)** is an extant or area of land where surface water from rain, melting snow, or ice converges to a single point at a lower elevation, usually the exist of the basin where water joins another water body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean. Other terms that are used to describe drainage basins are catchment, catchment area, drainage area, river basin and water basin. The drainage basin includes both the streams and rivers that convey the water as well as the land surfaces from which water drains into those channels, and is separated from adjacent basins by a drainage divide. The drainage basin acts like a funnel, collecting all the water within the area covered by the basin and channelling it into a waterway. Each drainage basin is separated topographically from adjacent basins by a geographical barrier such as a ridge, hill or mountain, which is known as a water divide. In nature, drainage basins are dynamic because the water and sediment-producing areas expand and contract depending upon the catchment characteristics, the antecedent conditions prior to any water even, and the character of the water input. In the technical sense, a **watershed** refers to a divide that separates one drainage area from another drainage area. However, in some areas, the term is often used to mean the drainage basin or catchment area itself.
3. A **raw water collection point** (above or below ground) where the water accumulates, such as a lake, a river, or groundwater from an underground aquifer. Water in this form is considered "raw", as opposed to water which has been treated before consumption, such as "drinking water" or water which has been used in an materialization process, such as "waste water". Raw water may be transferred using uncovered ground-level aqueducts, covered tunnels or underground water pipes.
4. **Water on the landscape**:
    A. Underground in rocks, soil, and aquifers.
    B. At ground level in basins, ponds, lakes, etc.
    C. At ground level in channels, conduits, rivers, etc.
    D. In plants and animals.
5. **Water processing and purification** technologies.
6. **Water in storage** locations such as reservoirs, water tanks, or water towers. Smaller water systems may store the water in cisterns or pressure vessels. Tall buildings may also need to store water locally in pressure vessels in order for the water to reach the upper floors.
7. Additional **water pressurizing components** [beyond that of gravity due to elevation differentials] such as pumping stations, which may need to be situated at the outlet of underground or above ground reservoirs or cisterns (if gravity flow is impractical).
8. A **pipe network for distribution/transportation** of water to points of storage, transformation, or usage. Water is transferred using water pipes (usually underground).
9. **Input and output connections** the distribution/transportation network, including drains and faucets.

2.1 Raw water sources and catchment

The collection of water from a raw water source is referred to as **raw water collection/catchment**. The **Earth's water cycle** provides sources of water. Those sources of water are:

1. **Ground sources:** include groundwater, springs, hyporheic zones and aquifers. **Ground water** is water that moves in some manner through the "ground" (i.e., water that has "gone underground"). **Spring water** is water that has moved through the ground and reappeared on the surface of the land. If you travelled underground you would eventually get deep enough to find that all the rock around you is soaked with water. You'd have entered the "saturated zone". The height of water in the saturated zone is called the **water table**. In dry places, the water table is very deep, but in moist places, the water table is very shallow. When the water table is higher than the actual surface of the ground, there are streams, rivers, and lakes on the land (i.e., surface water). Ground water is partially "filtered" through the ground, and partially flows through rivers that disappear beneath the earth. Rain that soaks into the ground, rivers that disappear beneath the earth, melting snow are but a few of the sources that recharge the supply of underground water. Because of the many sources of recharge, ground water may contain any or all of the contaminants found in surface water as well as the dissolved minerals it picks up during its long stay underground. Collection technologies: welling technologies and distribution technologies (e.g., applied hydraulics and pumps).
2. **Surface water:** include rivers, streams, glaciers, including some a superficial cavity of some kind, like a dug well. As water travels over the surface of the land, it dissolves naturally occurring minerals and can pick up substances resulting from the presence of animals or from human activity. Surface water is exposed to many different "contaminants", such as foliage, wastes, -icides, algae, and many other organic and inorganic materials. Collection technologies: land restructuring technologies; catchment technologies; evaporation technologies; distribution technologies.
3. **Infiltration water:** is the process by which water on the ground surface enters the soil and moves downward via the pull of gravity.
4. **Precipitation water:** includes rain, hail, snow, fog, etc. Precipitation is any form of liquid or solid water particles that fall from the atmosphere and reach the surface of the Earth. Precipitation comes in many forms, but it all comes from the same general process. Collection technologies: rain water catchment technologies (e.g., rain barrels) and distribution technologies. Any surface with significant displacement is probably a good water catchment platform. Roofs and trees, for example, work for water catchment. Water rains down on the roof and it is channelled into a gutter that feeds into the water system.
5. **Biological sources:** such as plants and animals. Animals and plants contain water in their cellular structures, and animals have urine. Some plants directly produce a drinking "water" liquid. One of the most well known of these plants is the coconut palm tree. Drinking water can be collected from the transpiration of water. Most plants constantly transpire water vapor. The transpiration process leads to the release of water vapor from plants and soil into the air. The intent of this technique is to collect and condense plant-respirated water vapor. This is often done by placing a container over the plant and securing the opening. Collection technologies: desalination technology; evaporation technology; distillation technology; osmotic technology.
6. **Ocean water (salinated seawater):** - About 97 percent of the Earth's water can be found in the unified form of an ocean. The ocean covers about 71 percent of the Earth and is blue, while land makes up the other 29 percent and varies in colour. The large presence of an ocean gives the Earth the appearance of a blue marble. Collection technologies: desalination technology; evaporation technology; distillation technology; osmotic technology. Ocean breezes contain elements which are highly corrosive to various substances.
7. **Atmospheric sources:** Water is constantly evaporating into the air. Air can carry water, it is called 'humidity'. All breathable air has some degree of water vapor (moisture) present.
   A. **Relative humidity (RH)** is the amount of water vapor in the air. Water vapor is the gaseous state of water and is invisible to the human eye. Humidity indicates the likelihood of precipitation, dew, or fog. While humidity itself is a climate variable, it also interacts strongly with other climate variables. Humidity depends on water vaporization and condensation, which, in turn, mainly depends on temperature. Humidity is affected by winds and by rainfall. The most humid regions of the earth are generally located closer to the equator, near coastal regions. Relative humidity is not a good measure for how humid it feels outside. Humid air is less dense than dry air. Dewpoint is a more accurate measure of how humid it feels.
   B. **Dewpoint** is a measure of atmospheric moisture. The higher the dewpoint, the more

moisture in the air. It is the temperature measure to which air must be cooled to reach saturation (assuming air pressure and moisture content are constant). A higher dew point indicates more moisture present in the air. It is sometimes referred to as dew point temperature, and sometimes written as one word (dewpoint). Frost point is the dew point when temperatures are below freezing.

2.2 The water system network

A water system's nodes include:

1. Source-points:
   A. Definition: The source-point in a water system processing service refers to the initial location where raw or untreated water is drawn from its source, which can be a natural water body (like a river or lake), a well, or any other water supply.
   B. Role: This is where the water extraction process begins, and it may involve various mechanisms such as pumps or intake structures to collect water from the source.
2. Continuous storage:
   A. Definition: Continuous storage refers to containers or reservoirs within the water processing system where treated or partially treated water is stored for ongoing use or distribution. These storage points help maintain a consistent and reliable water supply even during fluctuations in demand or supply.
   B. Role: Continuous storage ensures that water is readily available to meet the needs of users without interruptions.
3. End-point:
   A. Definition: The end-point in a water system processing service is the final destination where treated water is delivered for usage in the habitat (by residents through habitat common and personal access, and in light-, medium-, and heavy-service production).
   B. Role: End-points are critical because they represent the ultimate beneficiaries of the treated water, and the goal is to provide safe and potable water to meet their needs.
4. Mobile/portable:
   A. Definition: Mobile or portable service points in a water system refer to units or systems designed to provide water treatment and distribution capabilities that can be moved or transported to different locations. These units are not fixed in one place but can be deployed as needed.
   B. Role: Mobile or portable service points are particularly useful in emergency situations, remote areas, or temporary operations where a fixed infrastructure is not available or practical. They ensure access to safe water in various contexts.

Water can be stored in the following ways:

1. Underground reservoirs; lakes; ponds; streams.
2. Water channels, wells, and pools.
3. Water containers including barrels, tanks, and other vessels.
4. Water pipes.
5. Water bottles.

2.3 Functional usages of water

The flow and composition of water can be controlled, and in some cases, reused and/or recycled. The habitat service water cycle (a.k.a., municipal water cycle, urban water cycle) involves the controlled usage, processing, and re-use of water in order to conserve it as a resource. The parameters for water quality are determined by the intended use. Work in the area of water quality tends to be focused on water that is treated for human consumption, industrial/production use, or intended for the environment.

There are at least the following functional usages for water:

1. Drinking water (a.k.a., potable water/”spring water”) - this is water that is safe for humans to drink and to use in nutrition preparation (i.e., food preparation).
2. Ecological cultivation and aquaculture - water for consumption, or a life-media, by other organisms in the ecology.
3. Good and service production (including medicine, cleaning, and other productive uses)
4. Washing and cleaning.
5. Recreating in (i.e., swimming ponds and pools).
6. As a “waste” recycling medium.
7. Hydronic radiant heat to flooring.
8. Power/Energy production - water turbine and electrolysis (water splitting) to produce hydrogen.
9. Power/Energy emergency control - fire suppressant.

> **NOTE:** *Electrolysis is the process of passing electricity through water and splitting the water into its component parts.*

2.3.1 The drainage process

A.k.a., Infiltration, seeping, excess water removal.

Drainage is the system or process by which water or other liquids are drained (removed) from a place. In general, drainage refers to the process of removing excess water and moisture from an area. Drainage is the natural or artificial removal of a surface's water and sub-surface water from an area with excess of water.

There are seven categories of drainage over a landscape (and hence, there are also seven primary categories of erosion):

1. **Sheet** - an area of land not any of the below.
2. **Rill (a.k.a., brook, stream)** - a small stream.
3. **Runnel (primary valley)** - a narrow channel in the ground for liquid to flow through.
4. **Creek** - is any natural stream of water that flows in a channel without defined banks.
5. **River** - is any natural stream of water that flows in a channel with defined banks.
6. **Delta** - is any wetlands that form as rivers empty their water and sediment into another body of water.

There are several types of drainage system to deal with water over a landscape and within buildings:

1. **Natural gravity infiltration (a.k.a., seeping)** into earth. Here, drainage is the process in which water leaches downward from the upper soil layers to lower layers via gravity. The earth/soil is the natural drain for landscape.
2. **Surface drainage** - use of technology to remove water from surfaces. Rain accumulation on flat surfaces can cause water pooling, leading to water damage and mosquito breeding facilitation. Water should move off of flat surfaces, often toward a drain. Surface drainage mediums are typically flat and tilted to allow water to run toward a drain.
3. **Subsurface drainage** - use of technology buried underneath the soil to remove water from areas of excess and channel it to a drain. They are made to remove excess water that builds up in the soil.
4. **Sewer drainage** - uses of technology in the form of a water transport network; a sewer network of water channels/conduits (sometimes large enough for a human to walk through, and sometimes not) that removes waste- and rain- water from a settlement and/or channels it appropriately for processing.

Soil compaction will affect drainage over a landscape. The infiltration rate of highly compacted soil is very low.

2.3.2 Water distribution access points

Water access points are the locations where water is accessible to systems, to the community, and to individuals.

Common water distribution access points include, but are not limited:

1. Buildings where water is used.
2. Portable stores of water (i.e., bottled water).
3. Swimming points.
4. Places where people move a lot for hydration and recreation (e.g., bodies of water and water fountains).
5. Ecosystem water distribution points (i.e., sprinklers).
6. Fire suppressant system distribution points.

3 Water quality

A.k.a., Water types, types of water.

Water quality testing is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well. By measuring the characteristics of water bodies we can determine its ability to sustain life and meet our productive and ecological needs.

"Pure" water is essentially non-existent in the natural environment. Natural water, whether in the atmosphere, on the ground surface, or under the ground, always contains dissolved minerals and gases as a result of its interaction with the atmosphere, minerals in rocks, organic matter, and living organisms. Water is dangerously good at dissolving things. Since water is a polar molecule, its positive end is attracted to negatively charged ions or the negative sides of other polar molecules, and its negative side is attracted to positively charged ions or the positive sides of other polar molecules.

Impurities in raw water are either **suspended** or **dissolved**. Suspended impurities include diseases organisms, silt, bacteria, and algae. Some disease organisms must be removed or destroyed before the water is safe to consume. Dissolved impurities include salts, (calcium, magnesium, and sodium), iron, manganese, and gases (oxygen, carbon dioxide, hydrogen sulfide, and nitrogen). These impurities must be reduced to levels acceptable for human consumption.

As water goes through the hydrologic cycle, it gathers many impurities. Dust, smoke, and gases fill the air and can contaminate rain, snow, hail, and sleet. As runoff, water picks up silt, chemicals, and disease organisms. Water is a carrier of many organisms which cause disease. As it enters the earth through infiltration, some of the suspended impurities may be filtered out. However, other minerals and chemicals are dissolved and carried along. As ground water, in underground reservoirs, it may contain disease organisms as well as harmful chemicals. In addition to the impurities in water resulting from infiltration, many are contributed by an industrialized society. Garbage, sewage, industrial waste, pesticides, and nuclear, biological, and chemical (NBC) agents are all possible contaminants of raw water.

DESIGN REQUIREMENT: *Drinking water must be free of anything that would degrade the human restoration and performance cycle. Additionally, it should not damage the materials used in its transportation and storage.*

In community, we scientifically monitor all water sources for quality (i.e., composition and condition). Generally, ground water (subsurface) and spring water has less chemical and biological contaminants than surface water, provided reasonable care is exercised in the selection of the well site or spring. Harmful microorganisms are usually reduced to tolerable levels by passage through the soil; however, the water should still be tested. Water collected from its raw source does not always require purification/modification.

Water quality is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards. The parameters for water quality are determined by the intended use.

Environmental indicators and parameters for water quality typically fall under six categories:

1. **Physical properties/indicators.**
   A. Temperature, specific conductance (EC), electrical conductance, conductivity, total dissolved solids (TDS) + hardness, total suspended solids (TSS), turbidity (a.k.a., transparency), odour, colour, taste, volume and depth.
2. **Chemical composition/indicators.**
   A. Potential hydrogen (pH), biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO) + oxidation-reduction potential (ORP), total hardness (TH), metals and metalloids, hormone analogues, pharmaceuticals, metabolites, surfactants, and all other chemical compounds organic/in-organic/natural/man-made which may be found in the water.
3. **Biological composition/indicators** (i.e., ecological assemblage - the collection of organisms in the aquatic ecology).
   A. Algae, phytoplankton, vegetation, fish, reptiles, insects, and all other aquatic life.
4. **Microbiological composition/Indicators.**
   A. Bacteria, protozoa, viruses.
5. **Radiological composition/indicators.**
   A. Radon, nuclear waste, nuclear medicines, and all other radioactive elements.
6. **Quantum electrodynamic coherency.**
   A. Structure + temperature of water molecules.
7. **Movement of water.**
   A. The properties of water vary naturally depending on the surrounding environment; hence, data collected about water quality must be interpreted in the context of the water body's particular environment and position in the catchment.
   B. **Flow** is the volume of fluid (in this case, water) that passes through a passage of any given section in a unit of time. Flow, for the purposes of measurement, is the **velocity** of water multiplied by the cross-sectional area of the stream. Flow is modified by conditions along

and around a waterway. The amount of any particular substance carried in the water is known as the **load**.

Biological assessment (bioassessment) is an evaluation of the condition of a water body based on the organisms living within it. It reveals cumulative effects, as opposed to chemical observation, which is representative only at the actual time of sampling. Biological systems reflect overall ecological integrity and integrate the effects of different stressors. Thus, their observation provides a broad measure of aggregate impact and fluctuating environmental conditions. The primary reason for bioassessment and monitoring is that degradation of water body habitats affects the biota using those habitats; therefore, the living organisms themselves provide the most direct means of assessing real environmental impacts.

3.1 International water standards

There are a variety of national and international standards related to water quality (*Safe Plumbing*, 2021):

1. **NSF/ANSI Standard 60** - A standard related to chemicals used to treat drinking water. Developed by NSF and conforming to the ANSI voluntary standard, the standard was accepted by the NSF board in 1988 to evaluate products, such as softeners and oxidizers, to assure that usage amounts safeguard the public health and safety.
2. **NSF/ANSI Standard 61** - A standard related to products that come in contact with drinking water. Developed by NSF and conforming to the ANSI voluntary standard, the standard was accepted by the NSF board in 1988 to confirm that such products will not contribute excessive levels of contaminants into drinking water. Most U.S. states and many Canadian provinces require products used in municipal water distribution systems and building plumbing systems to comply with Standard 61.
3. **USA, California, Proposition 65** - Also known colloquially as Prop 65, California's Safe Drinking Water and Toxic Enforcement Act of 1986 requires companies to post notice of chemicals in products that can be released into the environment and have been determined by the state to be a cause of cancer. In early 2008, the list included 775 chemicals. Prop 65 impacts residents in other states when they receive such notices in purchased products, such as bathroom faucets. Companies will often post the notification on all products, rather than incur extra costs to isolate products sold only in California.
4. **USA, Safe Drinking Water Act (SDWA)** - The Safe Drinking Water Act (SDWA) is a federal law originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. Amendments were passed in 1986 and in 1996. The SDWA requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and ground water wells. SDWA authorizes the United States Environmental Protection Agency to set national health-based standards for drinking water to protect against both naturally occurring and man-made contaminants. Enforcement is accomplished through the National Primary Drinking Water Regulations.

3.2 Water indicators

There are a host of indicators that must be measured for in relation to the object, water.

Physical indicators include:

1. **Temperature** - the degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale and shown by a thermometer or perceived by touch. Temperature is a physical property of water that quantitatively expresses hot and cold. The temperature of a water body directly affects many physical, biological and chemical characteristics. Temperature is measured in Celsius.
   A. Water changes phase at specific temperatures (accounting for pressure).
   B. The temperature of a body of water influences its overall quality and ecology. Warm waters are more susceptible to eutrophication — a build-up of nutrients and possible algal blooms — because photosynthesis and bacterial decomposition both work faster at higher temperatures. Oxygen is less soluble in warmer water and this can affect aquatic life. By contrast, salts are more soluble in warmer water, so temperature can affect the water's salinity. Temperature directly affects the metabolic rate of plants and animals. Aquatic species have evolved to live in water of specific temperatures. If the water becomes colder or warmer, the organisms do not function as effectively, and become more susceptible to toxic wastes, parasites and diseases. With extreme temperature change, many organisms will die. Changes in long-term temperature average may cause differences in the species that are present in the ecosystem.
   C. If the water temperature changes by even a few

degrees, it could indicate a source of unnatural warming of the water or thermal pollution.

D. Factors that affect water temperature: air temperature; air movement; amount of shade and sunlight; soil erosion increasing turbidity; thermal pollution; water depth and volume; confluence of water movement.

E. Effects of water temperature: suspended and dissolved solids are changed; solubility of dissolved gas; rate of plant growth; metabolic rate of organisms; resistance of organisms.

2. **Pressure** - the amount of force placed on a body of water (measured in a unit of force per area).
   A. This force may come from:
      1. Gravity (pull),
      2. Temperature (evaporative boiler), and/or
      3. Mechanical pressurization (push).
   B. This pressure is measured in various systems of units:
      1. PSI (Pounds per square inch)
      2. Pa (pascals)
      3. Newtons per square meter
      4. Kilograms per square centimeter
3. **Flow** - the volume of water passing a location at a given point of time (measured in a unit of volume per unit of time).
   A. This rate may come from:
      1. Gravity (pull).
      2. Temperature (evaporative boiler).
      3. Mechanical pressurization (push).
   B. This flow is measured in various systems of units:
   C. Cubic [centi-]meter per second.
   D. Liter per second = 0.001 cubic meter per second.
4. **Volume** - the amount of water present.
   A. Cubic [centi-]meter.
   B. Liter = 0.001 cubic meter.
5. **Electrical conductivity (EC)** is the property of a substance which enables it to serve as a channel for medium for electricity. It is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and sulphates, and carbonate compounds. Compounds that dissolve into ions are also known as electrolytes. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is. Distilled or deionized water can act as an insulator due to its very low (if not negligible) conductivity value. Sea water, on the other hand, has a very high conductivity. Conductivity, in particular specific conductance, is one of the most useful and commonly measured water quality parameters. In addition to being the basis of most salinity and total dissolved solids calculations, conductivity is an early indicator of change in a water system. Salty water conducts electricity more readily than purer water. There are a number of scales used in EC, most commonly micro-Siemens (μS) or milli-Siemens (mS). For example, if a particular application calls for water with "2.0 EC," this is an incorrect determination. Most likely, the application is calling for an EC level of 2.0 mS. 2.0 mS = 2000 μS.
6. **Total Dissolved Solids (TDS)** is a measure of the combined/total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/L), also referred to as parts per million (ppm). TDS is a measure of the combined content of all inorganic and organic substances. The TDS of water is composed of mineral salts and small amounts of other inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended form. A TDS measure combines the sum of all ion particles that are smaller than 2 microns (0.0002 cm). Generally the operational definition is that the solids must be small enough to survive filtration through a filter with two-micrometer (nominal size, or smaller) pores. There are three primary classifications of water, based on the concentration of total dissolved solids:
   A. **Fresh** - TDS less than 1,000 - 1,500 ppm (milligrams-per-liter of dissolved solids).
   B. **Brackish** - TDS between 1,500 ppm and 16,00 ppm; Brackish water (less commonly brack water) is salt water and fresh water mixed together.
   C. **Salt water** (seawater) - TDS greater than 15,000 ppm.
7. **Hardness** in water is caused by calcium (Ca^{2+}) and magnesium (Mg^{2+}) - two nontoxic, naturally occurring minerals in water. Water hardness is typically reported in grains per gallon, milligrams per liter (mg/l) or parts per million (ppm). One grain of hardness equals approximately 17.1 ppm (mg/L) in TDS. Excessive hardness makes it difficult for soap to lather, leaves spots on dishware, reduces water flow, and can cause pipe, valve, and drain "scaling".
   A. **Soft water** - water with a low mineral content. Water softening is the removal of calcium, magnesium, and certain other metal cations in hard water. The resulting soft water is more

compatible with soap and extends the lifetime of plumbing. However, soft water is more acidic and may leach minerals like cadmium from metal pipes.

B. **Hard water** - water with a high mineral content. Note that mineral waters (with appropriate quantities and types of minerals) are often better for drinking that soft water.

8. **Turbidity** is the measure of relative clarity of a liquid. It refers to the opacity or muddiness caused by particles of extraneous matter. Turbidity is measured in nephelometric turbidity units (NTU). The instrument used for measuring it is called nephelometer or turbidimeter, which measures the intensity of light scattered at 90 degrees as a beam of light passes through a water sample. In general, the more material that is suspended in water, the greater is the water's turbidity and the lower its clarity. Turbidity affects how far light can penetrate into the water. It is not related to water colour: tannin-rich waters that flow through peaty areas are highly coloured but are usually clear, with very low turbidity. Measures of turbidity are not measures of the concentration, type or size of particles present, though turbidity is often used as an indicator of the total amount of material suspended in the water (called total suspended solids). Turbidity can indicate the presence of sediment that has run off from construction, agricultural practices, logging or industrial discharges.
   A. Suspended particles absorb heat, so water temperature rises faster in turbid water than it does in clear water. Then, since warm water holds less dissolved oxygen than cold water, the concentration of dissolved oxygen decreases.
   B. If penetration of light into the water is restricted, photosynthesis of green plants in the water is also restricted. This means less food and oxygen is available for aquatic animals. Plants that can either photosynthesise in low light or control their position in the water, such as blue-green algae, have an advantage in highly turbid waters.
   C. Regular turbidity monitoring may detect changes to erosion patterns in the catchment over time. Event monitoring (before, during and immediately after rain) above and below suspected sources of sediment can indicate the extent of particular runoff problems.
9. **Life activity** is a measure of the type, quantity, and size of organisms living in the water, from the microscopic to the macro.

Chemical indicators include:

1. **pH (potential hydrogen) -** The measured indicator for acidity or alkalinity is known as the pH value. A pH value of 7 means a substance is neutral, water with a pH lower than 7 is considered acidic and with a pH greater than 7 water is considered alkaline. The normal range for pH in surface water systems is 6.5 to 8.5. Potential hydrogen is measured with a pH meter.
2. **Dissolved oxygen (DO)** refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. In limnology (the study of lakes), dissolved oxygen is an essential factor second only to water itself. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality. Dissolved oxygen is a measure of the quantity of oxygen present in water (it has nothing to do with the oxygen atoms within the water molecules).
   A. Oxygen is essential for almost all forms of life. Aquatic animals, plants and most bacteria need it for respiration (getting energy from food), as well as for some chemical reactions. The concentration of dissolved oxygen is an important indicator of the health of the aquatic ecosystem. Persistently low dissolved oxygen will harm most aquatic life because there will not be enough for them to use.
   B. In some circumstances, water can contain too much oxygen and is said to be supersaturated with oxygen. This can be dangerous for fish. Supersaturated conditions occur in highly turbulent waters in turbines and at spillways, because of aeration, and also on sunny days in waters experiencing algal blooms or with many aquatic plants, because of photosynthesis. In this supersaturated environment, the oxygen concentration in fishes' blood rises. When the fish swim out into water that has less dissolved oxygen, bubbles of oxygen quickly form in their blood, harming the circulation.
   C. The air is one source of dissolved oxygen, and aquatic plants, including algae, are another. The speed at which oxygen from the air enters and mixes through a water body depends on the amount of agitation at the water surface, the depth of the water body and the rate at which it mixes itself. As water temperature rises, oxygen diffuses out of the water into the atmosphere.
   D. Dissolved oxygen concentrations change with the seasons, as well as daily, as the temperature

of the water changes. At very high altitudes, the low atmospheric pressure means dissolved oxygen concentrations are lower

E. Deep muddy lowland rivers, which contain more organic matter than upland streams, are likely to have lower dissolved oxygen concentrations than upland streams because bacteria are using the oxygen to break down the organic matter. Likewise, dissolved oxygen is usually lower than normal after storms have washed organic materials into any water body. Aquatic plants photosynthesise during daylight and increase dissolved oxygen concentrations around them.

3. **Oxidation-reduction potential (ORP)** is a measurement of water's ability to oxidize contaminants. The higher the ORP, the greater the number of oxidizing agents. Checking ORP is a simple method to monitor the effectiveness of a sanitizer or the quantity of anti-oxidants in a liquid. The ORP level of water can also be viewed as the level of bacterial activity of the water because a direct link occurs between ORP level and the count of certain bacterial species in water. ORP sensors work by measuring the dissolved oxygen. An ORP meter measures very small voltages generated with a probe placed in water. The electrode is made of platinum or gold, which reversibly looses its electrons to the oxidizer. A voltage is generated which is compared to a silver (reference) electrode in a silver salt solution, similar to a pH probe. The more oxidizer available, the greater the voltage difference between the solutions. ORP cannot be used as a direct indicator of dissolved ozone residual, except in very clean water applications. If there is ozone in the water, then ORP is a convenient measure of ozone's ability to perform a chemical task.

The temperature of water affects how quickly substances dissolve in it and, in some cases, the quantity that can be dissolved: for example, warm water holds less dissolved oxygen than colder water, but it holds more of most solids. Temperature also has a major effect on living things within the water. Compared to air or soil, bodies of water change temperature slowly, so aquatic life is generally not exposed to sudden fluctuations of temperature.

3.3 Grades of water

A.k.a., Types of water, water classifications, categories of water.

There are many different "grades" of water. The common classifications for water are:

1. **Drinking water (drinking-water)** is water that is suitable for drinking. Drinking water is both potable and palatable. Drinking water is the minimum quality of water that should be used for the preparation of productive substances. Once produced, drinking water has to be protected from microorganisms and contaminants that can enter the water through the pipelines that transport it to households. This happens by means of disinfection with various disinfection agents.
   A. **Potable water** (meaning drinkable or fit to drink) is water that is free from disease-producing organisms, poisonous and toxic substances, chemical or biological agents, and radioactive elements, which make it unfit for human consumption or other uses. This is water that is satisfactory for drinking, culinary and domestic purposes.
   B. **Palatable water** is water that is pleasing in appearance and taste. It is significantly free from colour, turbidity, taste, and odor. It should also be cool and aerated. Water may be palatable and at the same time not be potable. However, visual inspection cannot determine if water is of appropriate quality to drink.
2. **Filtered water** is water that has been processed at a basic level to remove chemicals, biologicals, suspended solids, and gases.
3. **Purified water** is water that has been processed to meet the requirements for ionic and organic chemical purity, and is protected from microbial contamination. In other words, purified water is generally free of dissolved minerals. While not all filtered water is purified water, all purified water has been filtered. The minimum quality of source or "feed water" for the production of purified water is drinking water. "Purified" water, being essentially free of minerals, is an active absorber (i.e., it is "aggressive"), in that it tends to dissolve substances with which it is in contact. Notably, when it comes into contact with air, carbon dioxide from the air is rapidly absorbed, making the water acidic and even more "aggressive". Many metals are dissolved by purified water.
4. **Black water (blackwater)** is water that contains animal, human, or food waste. Black water is also referred to as sewage, wastewater and sewer water. Blackwater generally travels from where it is produced as sewage to either an on-site septic system or a water processing system prior to its release into an ecosystem. In general, blackwater can be sent to a biodigester, then go through two filters, then go through a patch of plant filters (e.g., banana plants), before returning back to the clean

water table.

5. **Grey water (greywater)** is used water from bathroom sinks, showers, tubs, and washing machines. It is not water that has come into contact with feces, either from the toilet or from washing diapers. Grey water may contain traces of dirt, food, grease, hair, and biodegradable cleaning products. If grey water does not include pharmaceuticals, corrosive chemicals, or industrial soaps, then it can be used to irrigate a garden.
6. **Waste water (wastewater)** is any water that has been adversely affected in quality by anthropogenic influence.
7. **Recycled/reclaimed water** is water that has been processed and captured for reuse.
8. **Green water (natural, hydrological cycle water)** is water already in the natural hydrological cycle. Green water is water in the environment, as rain, water in ponds, in plants, and in animals. Essentially water rained onto the ground, as well as the moisture in the ground, and the water in organisms on the landscape. For instance, it rains, grass grow, cows eat grass, cows urinate, it rains, and moisture in soil refills aquifers. Water in the natural ecological cycle. Green water cannot be counted as a loss, because it remains in the ecological cycle. Of note, cattle livestock on pasture land use mostly green water (i.e., they use mostly water already in the local environment). Properly grazed grazing animals will increase the carbon in the soil as well as the soil capacity for holding water. They can facilitate the greenwater cycle in producing more abundant soil. The animals drink green water and then urinate the water back on the landscape after they retain it in their bodies for a time. In effect, animals on landscape are a partial store of water (on the landscape).
9. **Blue water** is water in lakes, rivers, oceans, and aquifers. To see blue water, look down on a map and see a blue color. Blue and green water are synonymous in some cases.

Water types can also be classified in the following way:

1. **White water (clean water, drinking water)** - Clean white water is safe to drink.
2. **Waste water (effluent water, sanitary water, sewer water, etc.)** - Once you use your white water, it is considered wastewater and is not fit for human consumption or washing or bathing because it contains bacteria, pathogens and chemicals, like soaps and detergents. There are two types of wastewater, including blackwater and greywater. Each type of effluent contains resources that can be best used and cycled through different sanitation cycling systems.

A. **Blackwater (black water)** - Blackwater in a sanitation context denotes wastewater from toilets, which likely contains pathogens. Blackwater can contain feces, urine, water and toilet paper from flush toilets. It may also contain "other" chemicals. Blackwater has come in contact with organic matter, like food particles, and human and/or pet waste. This water is considered dangerous because it can contain harmful pathogens, like bacteria and viruses. Heavily contaminated water can also come from natural floods where heavy rain causes rivers and streams to overflow. During this scenario, river water can mix with sewer water, creating blackwater. This water can cause illnesses. Blackwater can be sub-divided into:

1. **Brown water** - Same composition as black water, but no urine. Separation can be achieved with a urine diversion separation in the toilet basin. This water is treated like black water.
2. **Yellow water** - contains water and urine. This water is treated as greywater.

B. **Greywater (grey water, gray water, graywater)** - Greywater is the classification for water that has been used for washing. This water can contain soap and other dirt and debris, and it results from washing a load of dishes, wash clothes, mopping floors, washing hands and bodies. Unlike white water, gray water may contain soap particles, fat and oil from cooking, hair, fibers, food, and even flakes of human skin. It can still contain other chemicals also. The exact contents of gray water depend heavily on the household producing it; hence to safely re-use greywater, the users' must only put down the drain what can knowingly be re-cycled using few simple processes. While grey water shouldn’t be used for cooking or drinking, some people choose to recycle it to water their lawns, compost areas, and plant beds. Blackwater is distinguishable from greywater; greywater comes from sinks, baths, washing machines, and other kitchen appliances, and blackwater comes from toilets (and similar potentially high-pathogen and chemical types of drains). Greywater has not come in contact with human or pet excrement. This lack of contamination greatly decreases the risk of disease and increases the speed at which it can be broken down and safely reabsorbed into an active garden or lawn. However, it is important to understand that greywater can turn into blackwater in as little as 48 hours. The degree of gray (or, safety of grey) a water may be, however, comes down to a number of possible additions made in the acts of washing, bathing, cooking and cleaning. If the household chemicals in gray water are kept to a minimum, most plants will be able to handle it. You can keep chemical contamination to a minimum by using environmentally friendly, biodegradable soaps and detergents whenever possible. In commercial and residential buildings that are seeking to be more environmentally friendly, the greywater is funnelled through a separate drainage system so that it can be reused. It this automated systems, the slightly contaminated wastewater can be stored in a tank and sent back to be used in toilets and for irrigation systems in order to reduce overall water usage. Note: In some jurisdictions, using water from toilets, kitchen sinks, dishwashers, photo lab sinks and garage floor drains is illegal. Grey water can be sub-divided:

1. **Kitchen sink grey water:** contains more material organics and fats. This type of grey water is sometimes classified as black water because of the loads and types of work sometimes performed at the kitchen sink.
2. **Clear grey water:** all other gray water than water from the kitchen sink.

C. **Rainwater** - Rainwater is obviously rain that has fallen out of the sky. In a conventional building, this water is discharged to a surface water sewer, combined sewer, or a soakaway; if it is stored for use back in the building it is still rainwater, until it is used. Once it is used it becomes either foul water (if used to flush WCs or urinals) or waste water if used for washing clothes. If wastewater from a bath, basin or shower is collected for re-use it becomes greywater. If greywater is used to flush WCs it becomes foul water. If it is used in washing machines it becomes waste water (but would not circulate through the greywater recycling system again as waste water from washing machines has too many detergents in it to be considered as suitable for greywater recycling).

D. **Brackish water** - water occurring in a natural environment that has more salinity than freshwater, but not as much as seawater.

3. **Sewage treatment water**

A. Direct re-use - The planned and deliberate use of treated sewage. The sewage effluent is cleaned to potable water standard and injected directly into the mains supplying a town or city. However, most direct re-use systems clean the sewage effluent so that it is considered fit for purpose for irrigation, WC flushing and urinal flushing, and supply a secondary network of distribution pipework for this water as well as a mains supply network.

B. Indirect re-use - Water that is taken from a river, lake or aquifer that has received sewage or sewage effluent. With planned indirect water re-use the sewage effluent is discharged immediately upstream of the water treatment plant or used to recharge aquifers. Indirect re-use of sewage effluent is beginning to be used far more around the world as water demand increases and the water suppliers need a guaranteed supply.

4 Water processing

> **NOTE:** *Nature makes water "pure" by heating it up, causing evaporation, then eventually condensing into clouds, and finally, falling back to the earth as rain (or snow). However, when water passes through the atmosphere it will pickup pollutants present therein.*

The objective of water processing is to produce water that meets the specified requirements of a specific purpose. Water may be processed so that it is fit for human consumption (as "drinking water"). Water processing may also be designed for a variety of other purposes, including fulfilling the requirements of medical, chemical, and other applications. The most well-known water process is that of water filtration. However, water processing may also include the restructuring of water and the addition of elements to the water, as well as modification of the water's properties, including pH and temperature.

In industry, the processes that make water more acceptable for an end-use, which may be drinking, industry, or medicine are called "water treatment". The term "water treatment" generally refers to potable water production from raw water, whereas "wastewater treatment" refers to the treatment of polluted water, where the pollution could be from human waste, industry, agricultural waste or other sources of pollution.

Many people assume that the water flushed down their drains is of little consequence to the environment, with any contaminants of concern being removed by wastewater treatment plants. In reality, however, most wastewater treatment plants are not equipped to remove various medications and other chemicals that may end up being flushed or poured down your drain. They end up being continuously recycled through a populations water supply and accumulate over time.

4.1 Holistic water processing

While land and waterways can naturally treating effluent (e.g., sewage and stormwater), everything has a capacity. Where humans have concentrated in higher social density in habitats, sewage treatment mechanisms are required, in order to promote health and prevent nearby natural waterways from becoming polluted with human sewage. While natural ecological decomposition networks (e.g., an effluent ecological pond network) can appropriately decompose and process most organic waste, there are circumstances where waste streams carry more hazardous materials. Such materials include, but are in no way limited to common home-user products, such as, medicines, household cleaners, and technological waste. A holistic habitat water processing system uses an appropriate mix and master-planned mix of:

1. **Ecological water networks** (most frequently, watershed bodies). Here, functional watershed units move water and decompose effluent (waste streams).
2. **Infrastructural water networks** (a.k.a., water retaining) systems. Here, "green" infrastructures move, infiltrate and collect water, as specified.
3. **Water purification and reclamation technologies**:
   A. Water purification involves filtration technologies, including membrane bioreactors (MBR), moving bed biofilm reactors (MBBR), integrated fixed-film activated sludge (IFAS) systems, granulated activated carbon (GAC) filtration, and ozonation to remove contaminants from water. Here, water filtration technologies purify water to the level specified.
   B. Water reclamation involves the treating of wastewater to a level suitable for reuse in non-potable and/or potable applications. This step is crucial for conserving freshwater resources and promoting sustainable water practices.

4.2 Water processes

There are different categories of processes that occur to water.

4.2.1 Physical water processes

Physical water processes (technologies) include:

1. **Distillation** is a process of separating the component substances from a liquid mixture by selective **evaporation** and **condensation**. It is a change of state, or a way of separating mixtures. It is the process in which water is evaporated (by an evaporator) and the vapor condensed (by a condenser). It is important to understand that evaporation is not the same as condensation although evaporation in an enclosed environment can subsequently lead to the condition of condensation as evaporated moisture is "condensed" out of the air and is reverted to a liquid stage. Distillation may result in essentially complete separation (nearly pure components), or it may be a partial separation that increases the concentration of selected components of the mixture. In either case the process exploits differences in the volatility of a mixture's components. Distillation is a physical separation process and not a chemical reaction. The process of distillation essentially purifies water by heating it until only the water molecules evaporate and condense in another part of the filter, leaving impurities behind in the original water source. Water and dissolved salts can

be separated by distillation. Scientists consider distilled water an unnaturally pure form of drinking water and as a result, substances are routinely added to remineralize it. Minerals are considered a nutritionally necessary (i.e., "healthy") part of drinking water. Distilled water has an exceptionally low TDS, and it is often remineralized before being used as drinking water. Vapor compression distillation (technology: Slingshot water purifier). Solar distillation

2. **Alcoholic distillation** produces a usable/drinkable concentrate of ethyl alcohol through distillation of a mixture produced from alcoholic fermentation. Distillation comes after the brewing/fermenting of a material (mixed with water) into an alcoholic solution. The product of alcoholic distillation is a water alcohol solution with disinfection, and other, properties. The distillation process purifies the solution, and removes diluting components like water, for the purpose of increasing its proportion of alcohol content (commonly expressed as alcohol by volume, ABV). There are methods for purifying alcohol to anhydrous ethanol. Alcohol can be distilled to 99.6% pure using a valved reflux still.
    A. **Ethyl alcohol (ethanol)**, the alcohol in alcoholic beverages, is a bacterial metabolite produced by the fermentation of sugar molecules found in various natural substances. It is a by-product of bacterial metabolism and is toxic to bacteria, as well as other organismal programs. Hence, alcohol disinfects, but also makes the result of distillation a poor hydration source. The higher the percentage of alcohol, the greater disinfection effect. Ethanol is also known as pure alcohol, grain alcohol and drinking alcohol. Ethyl alcohol is used in some cosmetics to enhance the absorption of other ingredients, which means that anything mixed with it is likely to move through the skin and into the bloodstream more easily. Ethanol is an "alcohol solvent". Alcohol is highly flammable. Ethyl alcohol has significant and noticeable consciousness altering properties when consumed. Pure ethanol will absorb water from the atmosphere.
    B. Any alcohol when consumed in enough of a quantity can be toxic (i.e., a toxicant); however, ethanol is a "natural" by-product of bacterial fermentation and is something our body is evolved to understand. Hence, ethanol is not is not in the same toxicant category as "unnatural toxic alcohols". "**Toxic alcohols**" are molecules which are not understood and responded to well by our human metabolism -- they cause our human physiology to systemically malfunction in various ways. They have similar harmful effects on most other organisms. This difference in relationship between categories relates to the way humans and other organisms respond when exposed to the substance [in the context of an emergently evolving biology]. To be more clear, medical practitioners refer to these alcohols as "toxic alcohols" due to their effect on human biophysiology. "Toxic alcohols" include, but are not limited to: methanol; ethylene glycol; propylene glycol; and isopropanol (isopropyl alcohol) -- these are all "alcohol solvents" like ethanol, and hence, skin contact will lead to some absorption. In the market-State, "toxic alcohols" are more readily available than ethanol, and are usually cheaper.
    C. **Denatured alcohol (SD, methylated spirits)** is ethanol that has additives to make it poisonous, extremely bad tasting, foul smelling or nauseating, to discourage recreational consumption. In some cases it is also dyed. The ethanol is made undrinkable. This alcohol is bad for your skin since it is drying and irritating, even though it has antibacterial, antiseptic, and astringent properties. In the market, denatured alcohol is used as a solvent and as fuel for alcohol burners and camping stoves. Because of the diversity of industrial uses for denatured alcohol, hundreds of additives and denaturing methods have been used. The main additive has traditionally been 10% methanol, giving rise to the term "methylated spirits". Other typical additives include isopropyl alcohol, acetone, methyl ethyl ketone, methyl isobutyl ketone, and denatonium. Methanol, also called methyl alcohol, is found in windshield wiper fluid, de-icing products, paint removers, photocopying fluid, shellacs, and embalming fluid. In humans, methanol is metabolized first to formaldehyde and then to formic acid or formate salts, which is poisonous to the central nervous system, and in sufficient concentration may cause blindness, coma, and death.
    D. **Isopropyl alcohol (a.k.a., rubbing alcohol, isopropanol, Iso, IPA)** is used similarly to ethanol, except it is more toxic than ethanol, but less drying to skin. It is a petrochemical product, and numerous tests have shown it to be a strong neurotoxin (significantly stronger than ethyl alcohol). Isopropyl, like ethanol, is absorbed through the skin -- skin contact with isopropyl alcohol should be avoided. Isopropyl alcohol is a popular alternative to

ethyl alcohol in commerce because it cannot be safely consumed by humans. Isopropyl alcohol cannot be used to purify water for human consumption. Isopropyl alcohol is a strong solvent and dissolves a wide range of non-polar compounds. It has the similar disinfectant properties to ethanol. It evaporates into the air quickly, and is relatively non-toxic in comparison to other petrochemical and synthesized solvents. After evaporation, isopropyl alcohol exists in the atmosphere in the gas phase. The dominant atmospheric loss process for isopropyl alcohol in the troposphere is by reaction with the hydroxyl radical. Based on this reaction, the atmospheric half-life and lifetime of isopropyl alcohol is estimated to be 1.9 days and 2.7 days, respectively (Atkinson, 1994). The major reaction product from this reaction is acetone (Atkinson, 1995). Disinfecting solutions generally consist of 60–70% solution of isopropyl alcohol in water. Water is required to open up membrane pores of bacteria, which acts as a gateway inside for isopropyl.

3. **Atmospheric water generation (AWG)** is a process that extracts water from surrounding, ambient air (i.e., from the water vapor in the air), and often, filters it to remove particulates and bacteria. The resulting water is clean and free of chemicals and other hazards. There is vapor/humidity in the air due to the evaporation of water from land. All air on Earth contains at least a little water. Hence, water generators, also known as "water makers", harvest the moisture suspended in humid air. They use one of three basic methods: water vapor in the air is condensed by cooling the air below its dew point (i.e., **condensation**); exposing the air to desiccants (i.e., **desiccation**); or pressurizing the air (i.e., **pressurization**). The most common method uses technology similar to the refrigerant-based air conditioner to condense the air into a liquid flow, filter it, and then store it in a carafe or other holding tank. The technical approach uses a water extraction method that relies on chemistry. It uses a cocktail of chemical salts to pull water out of the air. Salt is a natural desiccant, which means that it draws and holds moisture. In desiccant based water generators, humid air passes over a salt mixture. The wet salt is then heated to the boiling point. The steam is condensed and routed to filters for processing. To save on energy, a vacuum is employed to lower the boiling point of water. One big advantage to desiccant-based atmospheric water generation is that it's more energy efficient than the other practical options currently available. Typically, the reclaimed water is filtered a number of times to take out airborne particles and bacteria as part of the process. If the water sits in the reservoir for longer than a day or so, it's filtered again to keep it purified. Unlike a dehumidifier, an AWG is designed to render the water potable. If the atmosphere is contaminated, then the water produced purely from the AWG technology will be partially contaminated also. Atmospheric water generators don't work everywhere. To work effectively, a few conditions must be met: The temperature of the ambient air has to be at least a few degrees above freezing. The humidity should be above a certain concentration, too. The figure varies depending on the manufacturer and method of extraction, but 32 to 40 percent humidity is in the ball park. High altitude can also interfere with the process. Also, because an AWG condenses water from the air it acts as a dehumidifier, and it can be combined with air-conditioning technology.
4. **Passive water generation (air well or dew harvester)** have been used for millennia. An air well or aerial well is a structure or device that collects water by promoting the **condensation** of moisture from air (Read: it uses condensation to collect moisture). Designs for air wells are many and varied, but the simplest designs are completely passive, require no external energy source and have few, if any, moving parts. Three principal designs are used for air wells, designated as high mass, radiative, and active. It appears that air wells designed to promote condensation were used by the ancient Greeks to provide water to large populations.
5. **Sedimentation** is the tendency for particles in suspension to settle out of the fluid in which they are entrained and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them: these forces can be due to gravity (a physical process), centrifugal acceleration (a physical process), or electromagnetism (an electromagnetic process). Controlled sedimentation (in a sedimentation basin) is when water is left undisturbed to allow heavy particles to sink out, and greases and oils to rise to the surface. The material on the top and bottom of the tanks is skimmed away. In geology, sedimentation is often used as the opposite of erosion (i.e., the terminal end of sediment transport).
6. **Aeration** is the process of increasing the oxygen saturation of the water. Dissolved oxygen (DO) is a major contributor to water quality and a factor in the pH of water. Not only do fish and other aquatic

animals need it, but oxygen breathing aerobic bacteria decompose organic matter. When oxygen concentrations become low, anoxic conditions may develop which can decrease the ability of the water body to support life. Water aeration is often required in water bodies that suffer from anoxic conditions, usually caused by adjacent human activities such as sewage discharges, agricultural run-off, or over-baiting a fishing lake. Aeration is one method of for reducing algae growth in a water body. Any procedure by which oxygen is added to water can be considered a type of water aeration. This being the only criterion, there are a variety of ways to aerate water. These fall into two broad areas – surface aeration and subsurface aeration. There are a number of techniques and technologies available for both approaches. Natural aeration is a type of both sub-surface and surface aeration. It can occur through sub-surface aquatic plants. Through the natural process of photosynthesis, water plants release oxygen into the water providing it with the oxygen necessary for fish to live and aerobic bacteria to break down excess nutrients. Oxygen can be driven into the water when the wind disturbs the surface of the water body and natural aeration can occur through a movement of water caused by an incoming stream, waterfall, or even a strong flood. In large water bodies, autumn turn-over can introduce oxygen rich water into the oxygen poor hypolimnion.

A. A solar aeration unit (i.e., solar aerator) is a pump powered by solar energy that aerates a water body. Fountains are a form of aeration.

7. **Filtration** is commonly the mechanical or physical operation which is used for the separation of solids from fluids (liquids or gases) by interposing a medium through which only the fluid can pass. The fluid that passes through is called the filtrate. Oversize solids in the fluid are retained, but the separation is not complete; solids will be contaminated with some fluid and filtrate will contain fine particles (depending on the pore size and filter thickness). Filter media can be cleaned by rinsing with solvents or detergents, or may be cleaned by backwashing. Self-cleaning screen filters utilize point-of-suction backwashing to clean the screen without interrupting system flow. Passing water through a bed of sand and gravel is a common last step in water purification. As water filters through the sand, the remaining particles of suspended matter are trapped in the sand bed. In the filtration process, water flows on top of the sand bed and travels through the bed until it is collected at the bottom in underdrains. Filtered water flows from the underdrains into clear wells or filtered water reservoirs.
8. **Earth filtration** are made of various mineral media, including various types of clays, diatomaceous earth, glass (silica) and other fine particles. The media are blended, shaped by manual or mechanical methods, dried and then fired at various temperatures to achieve different pore sizes and filtration properties. Some are unfired to maintain an open pore structure for filtration. Most ceramic filters are easy to use and are a potentially sustainable technology. The availability of suitable raw materials and the appropriate technology to blend these raw materials, shape the filter units and then perhaps fire them in a kiln are the main technical and accessibility barriers. The need for inspection and other quality control measures, as well as appropriate testing for proper pore size are also important requirements for their production. Some units are brittle and fragile and therefore, can break during use. Broken filters, even if only slightly cracked, are unsuitable for removal of particles and microbial contaminants from water. Well constructed earth filters have been extensively tested for efficacy in reducing various waterborne microbial contaminants. Some of these are rated to remove at least 99.9999% of bacteria, such as Klebsiella terrigena, 99.99% of viruses, such as polioviruses and rotaviruses, and 99.9% of Giardia cysts and Cryptosporidium oocysts.
9. **Ground rock filtration** is the natural filtering of particles in water by porous rocks as it moves through the ground and reappears in the form of **spring water** or **well water**. Spring water is collected immediately at the source before other particles can dissolve into it.
10. **Carbon filtration** is a method of filtering that uses a bed of activated carbon to remove contaminants and impurities, using chemical absorption. Each particle/granule of carbon provides a large surface area/pore structure, allowing contaminants the maximum possible exposure to the active sites within the filter media. One pound (450 g) of activated carbon contains a surface area of approximately 100 acres (40 Hectares). **Activated carbon** is carbon that has been processed to increase its adsorption properties. Absorption is a process whereby [pollutant] molecules in the fluid become trapped inside the pore structure of the carbon substrate. Carbon filtering is commonly used for water and air filtration. Active charcoal carbon filters are most effective at removing chlorine, sediment, volatile organic compounds (VOCs), taste and odor from water. They are

not effective at removing minerals, salts, and dissolved inorganic compounds. Typical particle sizes that can be removed by carbon filters range from 0.5 to 50 micrometres. The particle size will be used as part of the filter description. The efficacy of a carbon filter is also based upon the flow rate regulation. When the water is allowed to flow through the filter at a slower rate, the contaminants are exposed to the filter media for a longer amount of time.

11. **Membrane filtration** (ultra/micro/nanofiltration) is a water separation process. Water processing membranes are thin sheets of material that are able to separate water from other elements based on properties such as size or charge. Water passes through a membrane; but depending on their size, larger particles, microorganisms, and other elements are separated out. Some of these systems are pressure driven and depend on water pressure to separate the particles based on size. Reverse osmosis and nanofiltration are two membrane technologies. Membranes are often made of plastic or ceramic, with tiny openings called pores through which the water is filtered. The smaller the pore, the greater quantity of pollutants rejected and the more energy needed to force the water through the membrane. Membrane filtration produces clean water ("permeate") and a "waste" stream (concentrate/retentate) is discharged that contains all of the material that has been filtered out. The higher the TDS of water, the more difficult it becomes to maintain a membrane filter.

    Membrane filter types include:

    A. **Hyper filtration (HF)** can separate larger ions and molecules from smaller ones. (0.0001 micron pore size)
    B. **Ultra filtration (UF)** using hollow fibres can filter the smallest bacteria. (0.01 to 0.1 micron)
    C. **Nano filtration (NF)** use membranes to filter viral organisms. (0.001 to 0.01 micron)

12. **Reverse osmosis (RO) membrane filtration** is a physical membrane process for separation of dissolved substances into two streams, permeate (purified) and concentrate (unpurified). Essentially, reverse osmosis (RO) is a physical process for the de-concentration of substances dissolved in liquids. The process occurs by drawing water through a fine membrane under pressure. While the process is comparatively slow, this type of purification system can rid water of almost any contaminant, including radioactive particulates. The filtered water is stored in a closed tank to prevent contamination. The RO process strips the water down to mostly H20 molecules, and hence, minerals are routinely re-added to improve the quality of the water (if it is to be used for drinking water). The pore size of reverse osmosis membranes is so small that mostly water passes through. The filtration generally begins with the water flowing first through an activated charcoal pre-filter where it is cleansed of large molecular materials. Next the water flows through the main RO filter (i.e., screen/diaphragm). The tiny water molecules easily pass through the half permeable ("semi-permeable") diaphragm, which functions like a screen with an extremely small mesh size (2-3 angstroms). Nearly, but not all, pollutants are substantially larger in their molecule size than the H2O (water) molecule; thus, the pollutants get caught in the reverse osmosis diaphragm. These filtered pollutants are then rinsed off by the next flow of water, and washed down the concentrate drain. In this way the diaphragm is constantly cleaned and prevented from accumulating pollutants. Reverse osmosis systems produce larger quantities of wastewater (or "concentrate") than most other systems. They can become clogged with clay or organic materials if particle-rich source water is not filtered first. Maintenance is generally not difficult, but it can be expensive since the main action required is to replace the membrane as necessary. Maintenance problems tend to involve leaking and fouling of membranes.

13. **Membrane bioreactors (MBR)** use a water purification process that integrates a perm-selective or semi-permeable filtration membrane with a biological process contained within a bioreactor. The anaerobic membrane bioreactor (AnMBR), which is a combination of the anaerobic biological wastewater treatment process and membrane filtration, represents a recent development in the high-rate anaerobic bioreactors.

14. **Dilution** is a natural process that occurs in nature when "pollution" occurs. Nature provides its flowing waters with the ability to restore themselves through their own self-purification processes. It was only when humans gathered in great numbers to form cities and created novel chemicals that the stream systems were not always able to recover from having received great quantities of waste. Note, the self-purification discussed here relates to the purification of organic matter only.

4.2.2 Biological water processes

Biological water processes include:

1. **Bacterial processes** are introduced, and they begin consuming the small particles of organic matter that remain in the water. To facilitate this, oxygen is pumped into the water to allow the bacteria to feed continuously, as low oxygen levels cause feeding rates to slow.
2. **Myco-filtration** as **mycological processes** is a biological approach to water purification that uses the web-like tissue of mushroom-forming fungi (i.e., mycelium) to capture and degrade environmental pollutants. Mycofiltration is a sustainable approach to storm water processing.
3. **Slow sand filters** are large open sand beds without any backwashing mechanism. They are excellent at removing coliform bacteria and protozoans such as Giardia and Cryptosporidium. A slow sand filter not only physically filters the water, but also provides biological treatment from an organic mat which naturally forms on the filter surface. A slow sand filter can reduce microbial contaminants without the high cost of coagulation or pre-processing chemicals needed for common high-rate filters. Slow sand filtration percolates source water slowly through a bed of porous sand, with the influent water introduced over the surface of the filter, and then drained from the bottom. Properly constructed, the filter consists of a tank, a bed of fine sand, a layer of gravel to support the sand, a system of underdrains to collect the filtered water, and a flow regulator to control the filtration rate. No chemicals are added to aid the filtration process. The slow sand filter reduces suspended organic and inorganic matter, and may remove some pathogenic organisms. A granular activated carbon (GAC) sandwich filter is a modified slow sand filter that removes organic material. The removal action includes a biological process in addition to physical and chemical ones. Slow sand filters are less effective at removing microorganisms from cold water because as temperatures decrease, the biological activity within the filter bed declines. Since the purification mechanism in a slow sand filter is essentially a biological process, its efficiency depends upon a balanced biological community in the schmutzdecke. A sticky mat of biological matter, called a “schmutzdecke,” forms on the sand surface, where particles are trapped and organic matter is biologically degraded. Slow sand filters rely on this cake filtration at the surface of the filter for particulate straining. As the surface cake develops during the filtration cycle, the cake assumes the dominant role in filtration rather than the granular media. A slow sand filter must be cleaned when the fine sand becomes clogged, which is measured by the head loss. The length of time between cleanings can range from several weeks to a year, depending on the raw water quality. The operator cleans the filter by scraping off the top layer of the filter bed. A ripening period of one to two days is required for scraped sand to produce a functioning biological filter. The filtered water quality is poor during this time and should not be used. Slow sand filter monitoring and operation is not complicated. Daily tasks include reading and recording head loss, raw and filtered water turbidity, flow rates, and disinfectant residual. If necessary, the operator should adjust the flow to bring water production in line with demand.

4.2.3 Chemical water processes

A chemical reaction is a process that leads to the transformation of one set of chemical substances to another.

Chemical water processes include:

1. **Ion exchange (IE or ix)** is a chemical water processing method involving reversible chemical reactions for removing dissolved ions from solution and replacing them with other similarly charged ions. In other words, undesirable contaminants are removed from water by exchange with another non-objectionable, or less objectionable substance. Both the contaminant and the exchanged substance must be dissolved and have the same type (+,-) of electrical charge. **Deionized water** (DI water, DIW or de-ionized water), often confused with demineralized water / DM water, is water that has had almost all of its mineral ions removed, such as cations like sodium, calcium, iron, and copper, and anions such as chloride and sulfate. Because most non-particulate water impurities are dissolved salts, **deionization** produces a high purity water that is generally similar to distilled water, and this process is quick and without scale buildup. However, deionization does not significantly remove uncharged organic molecules, viruses or bacteria, except by incidental trapping in the resin. Deionization can be done continuously and inexpensively using **electrodeionization**. Three types of deionization exist: co-current, counter-current, and mixed bed. **Water softening** is the removal of calcium, magnesium, and certain other metal cations in hard water. The resulting soft water is more compatible with soap and extends the lifetime of plumbing. Water softening is usually achieved using lime softening or ion-

exchange resins. As water flow through the water softener, it will pass through a resin, bed of small plastic beads or chemical matrix (called Zeolite) that will exchange the calcium and magnesium ions with sodium ions (salt). Therefore, the TDS level will remain virtually constant (there may be minor differences).

2. **pH adjustment** is typically done with chemicals, such as caustic soda, lime, soda ash, or sodium bicarbonate. One natural way to raise the pH of the ground water is through aeration. Aeration will strip off dissolved carbon dioxide and raise the pH of the water. If there is radon present in the water, it will also be stripped.
3. **Coagulation** and **Flocculation** - Particles suspended in water naturally repel other particles. They cannot join to form larger particles that would settle more quickly. Coagulation occurs when a coagulant is added to water to “destabilize” colloidal suspensions. A coagulant, such as alum, is added to the source water to overcome the repulsion between the particles. Flocculation involves gently mixing the water so that the particles can combine and form larger particles. Flocculation, in the field of chemistry, is a process wherein colloids come out of suspension in the form of floc or flake; either spontaneously or due to the addition of a clarifying agent. The action differs from precipitation in that, prior to flocculation, colloids are merely suspended in a liquid and not actually dissolved in a solution. In the flocculated system, there is no formation of a cake, since all the flocs are in the suspension. These processes are essential pre-processing for many water purification systems. In conventional coagulation-flocculation-sedimentation, a coagulant is added to the source water to create an attraction among the suspended particles. The mixture is slowly stirred to induce particles to clump together into “flocs.” The water is then moved into a quiet sedimentation basin to settle out the solids. Dissolved air flotation systems also add a coagulant and flocculate the suspended particles; but instead of using sedimentation, pressurized air bubbles force them to the water surface where they can be skimmed off. A flocculation-chlorination system has been developed as a point-of-use technology. It uses small packets of chemicals and simple equipment like buckets and a cloth filter to purify the water. Finally, lime softening is a technology typically used to “soften” water—that is, to remove calcium and magnesium mineral salts. In this case, the material that is settled out is not suspended sediment but dissolved salts.
4. **Ozone (O_3)**, or trioxygen, is an inorganic molecule with the chemical formula O_3. It is an unstable form of pure oxygen (0_2); it is a gas. Ozone the tri-atomic form of oxygen: instead of the normal arrangement of 2 atoms of oxygen (O_2), ozone is comprised of 3 atoms of oxygen (O_3). Ozone is nothing other than ionized oxygen. Ozone, however, doesn’t want to stay in that tri-atomic state very long and unless held in check or bound by other molecular couplings, ozone will usually break down from O_3 to O_2 + O_1 within 20 minutes (at approximately atmospheric pressure). O_1 is called a singlet oxygen atom and it is highly reactive - it is a powerful oxidant with bactericidal properties very similar to chlorine. Because ozone is highly reactive, it readily oxidizes (i.e., breaks down) organic matter. When ozone encounters another compound, one oxygen atom will break away, attach itself to the compound, and oxidize (“clean” or “purify”) it. Ozone quickly reverts back into oxygen, leaving nothing behind other than oxygen. In concentration, it will reduce or prevent the growth of micro-organisms including bacteria, viruses, cysts, spores, mold and mildew. Ozone is also effective in eliminating or controlling color, taste, and odor problems. It oxidizes iron and manganese into solid particles that can be filtered out. Ozone is produced in nature when the ultraviolet rays of the sun strike oxygen molecules. When this occurs stratospheric layer of the atmosphere, it creases what we know as the “ozone layer”. Nature also produces ozone near the earth’s surface. Ozone is created when lightening, air, and precipitation combine. The sweet, fresh smell after a thunderstorm is the smell of ozone gas. Its efficacy is not dependent upon pH as is that of chlorine. There are 3 common methods of producing ozone: hot spark as corona discharge (CD), ultraviolet light, and cold plasma. A typical ozone system consists of an ozone generator mounted on the wall of a storage tank. The system uses a pump to circulate the ozone through the water. And, a filter is generally placed inside an storage tank to catch particles. Rising bubbles of ozone and air cause water to be drawn through the filter and it cleans the water without a water pump. The ozonation process is currently the most effective, sustainable, and safest non-chemical method of eliminating bacteria from water. Due to the highly reactive nature of ozone, it can corrode some materials. Hence, all surfaces coming in contact with ozone should be made of ozone-resistant materials, such as stainless steel. Ozone is an irritant (i.e., caustic) to lung and nasal tissue at concentration, and

hence, generators may leak and could create an ozone hazard. However, ozone dissolved in water will not irritate skin, nose, or ears, nor will it dry out or leave a chemical film on skin. Ozone does not affect the pH balance of water like traditional chemical treatment methods. Ozone is a powerful sanitizer and oxidizer and reverts back into oxygen, leaving no harmful by-products whatsoever. Ozone can be used to purify a water body, including water in containers, storage tanks, spas, bathtubs, fountains, and wading pools. An ozonation system will sanitize the tank as well as the air above the water line. Most ozone systems require a storage tank for the treated water. With ozone treatment, disinfection occurs primarily at the point of contact between the ozone and the water. The disinfection process does not occur beyond the treatment unit. This contrasts with chlorination treatment where the residual chlorine remains in the water and continues the disinfection process for some time. Because ozone is so unstable, it does not produce a reliable residual. Ozone has an active residual time measured in minutes, whereas the active residual time for chlorine is measured in hours. Here, temperature is an important variable. The colder the water the more ozone will be dissolved in water and the longer the residual. Room temperature water looses its concentration of ozone within several minutes. Ozone is continuously moving out of solution and will dissipate completely from very cold water (context dependent) within about 20 minutes. In general, the lower the water temperature, the more ozone is dissolved in the water. Ozone has been found to be effective over a wide range of pH, but a pH slightly above 7 increases treatment efficiency. The ozone demand is related to the level of contamination in the water. When substances in the untreated water react with ozone, part of the ozone is used up, which may leave less ozone available to treat the targeted contaminants. Ozonation units are installed as a point-of-entry treatment system. At the point where the ozone mixes with the water, turbulence and bubbles are created (through aerated diffusion of the ozone); these ensure that the ozone contacts as much of the raw water as possible, and is dissolved into the water to some degree. The greater the water flow rate, aeration (e.g., “diffuser stone”), and pressure differential/turbulence, the more effective the “treatment”. The effectiveness of ozonation depends significantly on the contact time, temperature, and solubility. In general, ozone requires a shorter contact time than chlorine. Ozone treatment can produce harmful by-products in water. For example, if bromide is present in the raw water, ozone reacts with it to form bromate, shown to cause cancer in rats. The less humidity an ozone generator has to work with, the better the results. The perfect environment for ozone production is close to 15-38°c with no humidity. Ozone can still be made in an environment with high humidity (50-80%), but with an air drier, the ozone generator will double or even triple the amounts of ozone produced, cleaning your water in less time. An air drier will also lengthen the life of the ozone machine by allowing it to run more efficiently. After a period of time, an ozone machine (without an air dryer) converts moisture to an acidic yellow coloured paste. This paste build-up will ruin the ozone generator causing poor ozone performance. Most ozone systems do not require extensive maintenance. Some systems use an air-drying material, which needs to be replaced periodically. It is also necessary to periodically clean the water storage tank and check pumps, fans and valves for damage and wear. If UV radiation generates the ozone, the lamp must be replaced periodically. Any pre-treatment or post-treatment devices may require additional maintenance. Additional uses for ozone: Ozonated water can be used to sanitize surfaces when submerged in a sufficient concentration for a sufficient amount of time. In other words, it can be used to disinfect toothbrushes and dentures. It can be used as a gargling solution. I can be used as type of “air purifier”.

4.2.4 Electromagnetic processes

Electromagnetic water processes include:

1. **Ultraviolet (UV) radiation/energy** is found in the electromagnetic spectrum between visible light and x-rays and can best be described as invisible radiation with disinfection as a property. The ultraviolet bandwidth occupies wavelengths roughly between 200 and 400 nanometers. Purification via exposure to ultraviolet radiation (UV germicidal irradiation) is unique from other types of sterilization modalities due to the fact that it does not necessarily cause death of the target organism. In those pathogens it does not directly kill, the UV radiation effectively alters the organism’s genetic structure. UV energy penetrates the outer cell membrane, passes through the cell body and disrupts its DNA preventing reproduction. By causing damage to the target bacteria’s Deoxyribonucleic Acid (DNA), the bacteria is sterilized at the genetic level. Thus, the organism

is no longer able to reproduce and cause disease. The degree of inactivation by ultraviolet radiation is directly related to the UV dose applied to the water. The dosage, a product of UV light intensity and exposure time, is measured in microwatt second per square centimeter ($\mu ws/cm^2$). UV treatment does not alter water chemically; nothing is being added except energy. UV units only kill bacteria at one point in a watering system and do not provide any residual germicidal effect downstream. The sterilized microorganisms are not removed from the water -- bacteria cells are converted into pyrogens. The killed microorganisms and any other contaminants in the water are a food source for any bacteria that do survive downstream of the UV unit. Due to these limitations, the piping in a watering system treated by UV disinfection will need to be periodically sanitized with a chemical disinfectant. UV disinfection does not remove dissolved organics, inorganics or particles in the water. Although 100% destruction of microorganisms cannot be guaranteed, it is possible to achieve 99.9% reduction in certain applications and with proper maintenance. In order for a UV unit to successfully disinfect water, the following additional variables must be considered: Firstly, the composition of water can reduce the transmission of UV light through the water, which reduces the UV dose that reaches the bacteria. UV disinfection is most effective for treating high-clarity purified reverse osmosis or distilled water. Secondly, all UV units have a maximum flowrate capacity and some have a minimum flowrate as well. Finally, UV radiation generates ozone that can damage surrounding materials.

2. **Boiling** is the oldest water disinfection technique. Boiling is the rapid vaporization of a liquid, which occurs when a liquid is heated to its boiling point, the temperature at which the vapor pressure of the liquid is equal to the pressure exerted on the liquid by the surrounding environmental pressure. effective despite contaminants or particles present in it, and is a single step process which eliminates most microbes responsible for causing intestine related diseases. In places having a proper water purification system, it is recommended only as an emergency treatment method or for obtaining potable water in the wilderness or in rural areas, as it cannot remove chemical toxins or impurities.
3. **Steam and pressure sterilization** through the use of an autoclave. An autoclave is a pressure chamber used to sterilize materials by subjecting them to high pressure saturated steam for a duration of time.

4.2.5 Electrochemical water processes

Electrochemical approaches to water tend to emphasize the recovery of metals and chemicals, and the destruction of organic contaminants.

Electrochemical water processes include:

1. **Desalination** is the process of removing dissolved salts and minerals from seawater or brackish water. It is also called desalination or desalting. Desalination is an advanced technical process involving many different technologies, including distillation, reverse osmosis, electrochemical mediation, and membrane filtration. Desalination produces drinking water and concentrate (the water that contains the salts that were removed in the desalination process, which used to be called brine). Salt water is desalinated to produce fresh water suitable for human and ecological usage. The minerals in the concentrate can be separated to produce, at the very least, a large amount of salt and a complex mineral solution for the biological nutrition needs of various organisms, notably, vegetation In other words, ocean water can be desalinated to produce a complex mineral solution (i.e., nutrient source) for plants and other organisms.
2. **Electrodialysis** is a water processing system that uses electrical potential to remove charged impurities from water. It is widely used for the processing of brackish water and for the desalination of seawater. Unlike other membrane processes, the source water never passes through the membranes during electrodialysis. The migration of ions across the membrane under the influence of a potential gradient is the basis of electrodialysis. Early processes used a three-compartment cell and the membranes were non-selective. Today, an array of membranes are used with alternating cation-selectivity and anion-selectivity.
3. **Disinfection** is the chemical or biological destruction of pathogenic microorganisms such as viruses, protozoa, and bacteria, or at least the deactivation of those microorganisms. Several chemicals are used in water disinfection and electro-chemistry is involved in the production of those chemicals. Common disinfection chemicals include: halogens; chlorine (Cl); chloramine (NH_2Cl); chlorine dioxide (ClO2); bromine (Br); hypochlorite (ClO-); ozone (O^3); hydrogen peroxide (H202); and iodine (I). The importance of these chemicals is based predominantly on their oxidizing power. They provide a flexible, controllable bioaction that

can be maintained throughout a water distribution system. However, these chemicals have varying **residual disinfection** properties.

A. **Ozone (O3)** is a strong oxidizing substance with bactericidal properties very similar to chlorine. It is claimed that ozone destroys bacteria more rapidly than chlorine and its efficacy is not dependent upon pH as is that of chlorine. The ozonation process is currently the most effective, sustainable, and safest non-chemical method of eliminating bacteria from water. Note, the major difference between ozone and UV is that ozone is a very powerful oxidizer and kills all known microorganisms—whereas UV typically just inactivates them. Ozone actually opens up the cell wall of the bacteria, virus, mold, fungus, etc. Then, because ozone oxidizes them (opens up the cell wall), the impurities clump together and are more easily filtered out. Water becomes clear with ozone, and the clearer the water is, the more effective UV is. Only clear water can be effectively treated with UV, cloudiness in the water can absorb the UV light. If you use UV, you should definitely use ozone too. But if you use ozone—you don't necessarily need UV. Ozone does everything UV does and more. But UV does not do everything that ozone does.

B. **Hydrogen peroxide** is a chemical compound with the formula H_2O_2. Hydrogen peroxide should really be called hydrogen dioxide. In its pure form, it is a colourless liquid, slightly more viscous than water; however, for safety reasons it is normally used as an aqueous solution. When exposed to other compounds hydrogen peroxide dismutates readily. The extra oxygen atom is released leaving H_20 (water). In nature oxygen (0_2) consists of two atoms--a very stable combination. H_20_2 is found naturally in rainwater. There is ozone (O_3) in the atmosphere, and when it rains, the unstable ozone gives up atoms of oxygen to falling water to form hydrogen peroxide. It turns out that this is one of the reasons that rainwater causes plants to grow more rapidly. In the human body, the cells responsible for fighting infection and foreign invaders in the body (your white blood cells) make hydrogen peroxide and use it to oxidize pathogens. Hydrogen peroxide is the simplest peroxide (a compound with an oxygen–oxygen single bond) and finds use as a strong oxidizer, bleaching agent and disinfectant. When stored under the proper conditions, it is a very stable compound. Concentrated hydrogen peroxide, or "high-test peroxide", is a reactive oxygen species and has been used as a propellant in rocketry. Pure hydrogen peroxide will explode if heated to boiling. Hence, for general usage, it is usually handled as a dilute solution. 3–6% H_2O_2 will not burn skin, but will kill bacteria on a wound. 32-35% (a.k.a., food grade) will burn skin on contact and is generally diluted before use. On human skin, peroxide reacts with melanin to oxidize it and convert it into a compound which is free of colour. Hydrogen peroxide's same oxidizing properties allow it to react with bacteria, viruses, spores, and yeasts, making it a functional disinfectant. It is rarely used in drinking water production as a stand-alone treatment process. Hydrogen peroxide solution may be used to disinfect surfaces. When it comes into contact with bacteria on a wound there is a fizzing and bubbling that happens, which is the result of the H_20_2 bonds breaking during the reaction. One of the oxygen molecules is liberated, leaving H_20. The free oxygen molecules are what you see bubbling to the surface. It has a variety of medical uses including that of mouthwash (wherein it whitens teeth) and used to treat fungal issues on tissue. Hydrogen peroxide is odorless and colorless, but not tasteless. It can also be used in the ear to treat ear infections. It can be used to disinfect surfaces like toothbrushes and countertops. It can be used as a bleach on skin, grout, hair, and clothes. It can be added to a clothes washing agent to facilitate cleaning and to bleach fabric. It can be used on vegetables and will disinfect/ sanitize utensils. Plant seeds can be soaked in a low-grade hydrogen peroxide solution to simulate rainwater. It can be used in aquatic environments to reduce algae.

C. **Chlorine** (and **chloramine**) is used to kill any harmful bacteria that might be present in a water source, and it is the most widely use disinfecting agent in early 21st century society. The amount of chlorine that is used is based on the amount of water that is treated, the amount of contaminants that must be controlled, and the time it takes for the water to reach its first usage (i.e., residual disinfection).

4. **Bleaching** refers to the usage of a number of chemicals which remove color, whiten or disinfect, often by oxidation. Chlorine is the basis for the most commonly used bleaches. Bleach performs two types of actions: it whitens, and has antimicrobial efficacy. There are two primary

classes of bleach: chlorine-based bleach and peroxide-based bleach. Sodium hypochlorite is the most commonly encountered bleaching agent, usually as a dilute (3–6%) solution in water. Chlorine bleach forms dioxin after contact with organic compounds. Dioxins are a group of chemically-related compounds that are persistent environmental pollutants (POPs). Dioxins are highly toxic and can cause reproductive and developmental problems, damage the immune system, interfere with hormones and also cause cancer.

4.2.6 Temperature change processes

Water resists temperature change, both for heating and cooling. Water can absorb or release large amounts of heat energy with little change in actual temperature. At sea level, pure water boils at 100oC and freezes at oC. The boiling temperature of water decreases at higher elevations (lower atmospheric pressure). For this reason, an egg will take longer to boil at higher altitudes. The high boiling point of water (similar sized molecules are normally gases at room temperature) is also due to its ability to form hydrogen bonds.

4.2.6.1 Water heating

Water heating is a thermodynamic process that uses an energy source to heat water above its initial temperature. Heated water is used for cooking, cleaning, bathing, space heating. In materialization and other services, hot water and water heated to steam have many uses. Water heating systems are categorized by their energy source and whether the system is tank-type or tankless.

1. **Tank-based water heating system** - either the storage tank is directly heated, or panels that cycle water through the storage tank are heated with an energy source such as solar, geothermal, or wood.
2. **Instantaneous water heating systems** - provide hot water on-demand at their point-of-use (POU). These systems may use a water storage tank, but the water in the tank is not hot; it becomes hot at its point of use.

4.2.6.2 Water cooling

A.k.a., Water chilling.

Herein, refrigeration technology is applied to water in order to reduce its temperature.

4.2.7 Ecological processes

The common ecological processes for processing water include, but may not be limited to:

1. Dehydration (evaporation).
2. Transpiration.
3. Digestion.
4. Absorption.
5. Filtration.
6. Sedimentation.
7. Infiltration.

Consider the role of water in the structure and function of ecological processes:

1. **Waste Stabilization Ponds (WSP) and Constructed Wetlands (CW) (**or **CWWSP)** are a form of wastewater and stormwater processing, which involve the construction of low energy-consuming ecosystems that use natural processes to transform, decompose, and recycle materials. A CWWSP forms a controlled ecological network of ponds (Read: a pond system) for the transformation, decomposition, and recycling of materials from used water and storm water. Together, the different ecological compositions of the ponds in the network, and the flow of water therein, form a unified ecological transformation system for processing water with a portion of the material effects of our living into sustainable building blocks (i.e., nutrients) for further life. Therein, interconnected pond water levels dictated by ground water levels. The pond system attract wildlife. It is essentially a system designed to mimic (as in, biomimicry) the way nature transforms water.
   A. **Waste Stabilization Ponds (WSP; a.k.a., anaerobic ponds)** are large, shallow basins in which raw sewage is processed (i.e., "treated") entirely by natural processes, primarily involving algae and bacteria. The ponds in the waste stabilization system are formed into a network, generally including three types of ponds:
      1. **Anaerobic ponds** - Anaerobic ponds are commonly 2 – 5m deep and receive wastewater with high organic loads (i.e., usually greater than 100 g biochemical oxygen demand (BOD)/m3 .day, equivalent to more than 3000 kg/ha.day for a depth of 3m). They normally do not contain dissolved oxygen or algae. In anaerobic ponds, BOD removal is achieved by sedimentation of solids, and subsequent anaerobic digestion in the resulting sludge.
      2. **Faculative ponds** - (1-2m deep) are of two types: Primary facultative ponds that receive raw wastewater, and secondary facultative ponds that receive particle-free wastewater (usually from anaerobic ponds, septic tanks, primary facultative ponds, and shallow sewerage systems). The process of oxidation

of organic matter by aerobic bacteria is usually dominant in primary facultative ponds or secondary facultative ponds.

3. **Maturation ponds (aerobic ponds)** are usually 1-1.5m deep, receive the effluent from the facultative ponds. Their primary function is to remove excreted pathogens. Although maturation ponds achieve only a small degree of BOD removal, their contribution to nutrient removal also can be significant. Maturation ponds usually show less vertical biological and physicochemical stratification, and are well-oxygenated throughout the day. The algal population in maturation ponds is much more diverse than that of the facultative ponds, with non-motile genera tending to

B. **Constructed wetlands (CW)** are planned systems designed and constructed to employ wetland vegetation to assist in processing wastewater in a more controlled environment than occurs in natural wetlands, but mirroring the way the natural wetlands function. Herein, aquatic plants as a bio-filter/bio-transformer. Essentially, a constructed wetland is a designed complex of saturated substrate, emergent and submerged vegetation, animal life, and water that simulate wetlands for human uses and fulfillment. In early 21st century society, constructed wetlands are an "eco-friendly" alternative for secondary and tertiary municipal and industrial wastewater treatment. The pollutants removed by CW's include organic materials, suspended solids, nutrients, pathogens, heavy metals and other toxic or hazardous pollutants. In municipal applications, they can follow traditional sewage treatment processes. Different types of constructed wetlands can effectively treat primary, secondary or tertiary treated sewage. However wetlands should not be used to treat raw sewage and, in industrial situations, the wastes may need to be pre-treated so that the biological elements of the wetlands can function effectively with the effluent. CW's are practical alternatives to conventional treatment of domestic sewage, industrial and agricultural wastes, storm water runoff, and acid mining drainage.

1. Constructed wetlands for wastewater treatment can be categorized as either **Free Water Surface (FWS)** or **Subsurface Flow (SSF)** systems. In FWS systems, the flow of water is above the ground, and plants are rooted in the sediment layer at the base of water column. In SSF systems, water flows though a porous media such as gravels or aggregates, in which the plants are rooted.
2. **Riverbank filtration (bank filtration)** - The improvement of water quality through natural filtration by soil and microbial processes caused by the percolation of water through natural or engineered media. Bank filtration involves installing a well near the surface water source to allow pulling water through the ground to effect some natural filtration. This concept requires granular soils adjacent to or under the surface water source. Where these conditions exist, there can be significant benefits with employing bank filtration.
3. **Reed beds** are natural habitats found in floodplains, waterlogged depressions and estuaries. Reed beds are part of a succession from young reed colonising open water or wet ground through a gradation of increasingly dry ground. As reed beds age, they build up a considerable litter layer which eventually rises above the water level, and ultimately provides opportunities for scrub or woodland invasion. Artificial reed beds are used as a method of removing pollutants from grey water, which will concentrate many of the undesirable elements of water into the stems of the plants given sufficient time. The Common Reed (Phragmites Australis) has the ability to transfer oxygen from its leaves, down through its stem, porous speta and rhizomes, and out via its root system into the rhizosphere (root system.) As a result of this action, a very high population of micro-organisms occurs in the rhizosphere, with zones of aerobic, anoxic, and anaerobic conditions. Therefore with the wastewater moving very slowly and carefully through the mass of reed roots, this liquid can be successfully treated, in a manner somewhat similar to the conventional biological filter bed systems of sewage treatment plants.

4.2.8 Emergency water purification processes

Each individual should select the clearest, cleanest water with the least odor and then process the water using individual water purification procedures from their knowledge skill-set. Productive technologies for emergency water purification include: bottled water; iodine tablets, chlorine ampules, boiling, earth-based filtration, hand operated water purifiers; spring water; and passive water generation techniques.

5 Rainwater infrastructural units and processes

A.k.a., Stormwater infrastructure untis and processes.

Infrastructure encompasses a wide range of objects that provide essential services and support various activities It could be said that there are two types of infrastructure in relation to water:

1. **Grey infrastructure (a.k.a., mineral-only water infrastructure, grey-water infrastructure, gray-water infrastructure)** - is the more traditional concrete, metal and machine systems that channels and processes water. Gray infrastructure relies on technology infrastructure; such as storm drains, concrete, pipes, pumps, dams, bridges, and chemicals.
2. **Green infrastructure (a.k.a., organics inclusive water infrastructure, green-water infrastructure, green infrastructural drainage, green drainage infrastructure)** - is an approach to water management that protects, restores, or mimics the natural water cycle. Green infrastructure encompasses a variety of vegetational (and some mineral) arrangements, mostly used to control the flow of water.

Drainage of rain in a sustainable urban drainage systems can provide an optimized water coordinated arrangement. A water masterplan can be designed to mimic natural drainage by adopting techniques to deal with surface water runoff locally, through collection, storage, and cleaning before allowing it to be released slowly back into the environment. These techniques seek to capture, use, delay or absorb rainwater, rather than reject it as a nuisance or problem.

5.1 Green infrastructural water units

A.k.a., Organics-inclusive water infrastructure, green infrastructure water, plant stormwater infrastructure, natural urban rainwater drainage, vegetative water channelling infrastructure, green-water infrastructure, blue-green infrastructure.

Green infrastructure is the set of practices that coordinate water using vegetation, such as vegetated rooftops, roadside plantings, absorbent gardens, and other measures that capture, filter, and route stormwater. This type of vegetative planting can significantly increases the quality and quantity of local water supplies and provides myriad other environmental benefits. It reduces the likelihood of flooding and pollution runoff that reaches sewers, streams, rivers, lakes, and oceans. Green infrastructure often captures the rain where it falls, mimicking natural hydrological processes and using natural elements, such as soil and plants. Note here that a permeable pavement, for example, could be considered a form of "green" infrastructure. A permeable pavement does not involve plants, but it does facilitate the natural hydrological cycle, and thus, could be considered "green". Most implementations of "green" infrastructure seek to optimize infiltration over the landscape (i.e., drainage/seepage into the earth) and channel excess [storm-]water to appropriate locations.

CLARIFICATIONS: *Note that the concept of "green" infrastructure (in the context of water) ought not be confused with the concept of "greenspace", which is simply vegetative placement for aesthetics and comfort (and sometimes, food). Nor should it be confused with the concept of "green" infrastructure beyond the context of water, such as willow planted fencing (wherein, the fence is infrastructure and the source is a live "green" plant). Of course, all outdoor "green" infrastructure will interface with stormwater.*

Examples of green infrastructure (techniques) that do include plants are:

1. Rain gardens (i.e., any garden open to the sky).
2. Green roofs (a.k.a., vegetated rooftops).
3. Blue roofs (i.e., roofs that collect and channel water).
4. Roadside plantings (a.k.a., pathway plantings, streetside plantings).
5. Green permeable pavers (a.k.a., green pavers, turf pavers).
6. Swales (i.e., swale and berms).
7. Bioswales (i.e., deep channels of native plants, grasses, flowers, and customized soils that often run parallel to paths).
8. Basins and ponds.
9. Absorbent gardens (for effluent).
10. Artificial wetlands (a.k.a., urban wetlands, constructed wetlands; to naturally treat water).
11. Hydrological features (e.g., ponds and swales).
12. Natural fencing.
13. Green wall/screen (a.k.a., vegetative walls).
14. Green building façades.

Green infrastructure requires continuous maintenance and monitoring because of the growing vegetation, and potential problems that can arise from growing vegetation. Maintenance for green vegetation includes, but may not be limited to:

1. Watering.
2. Feeding.
3. Pruning.
4. Check for infestations and disease.
5. Replacement (when vegetation dies or becomes

diseased).
6. Replanting (e.g., grass seeds).

5.1.1 Green roofs

Green roofs have several functions, including but not limited to:

1. Providing insulation for the building.
2. Reduces ambient temperatures by reducing temperatures on the roof surface and surrounding air. Green roofs can reduce the "heat island" effect seen in cities.
3. Purifies the atmosphere.
4. Provide biophilic beauty (only if property installed and maintained).
5. Becomes rainwater buffer by reducing stormwater runoff.
6. Attractive of a diverse wild ecology.

The significant down-side to green roofs is that they use an impermeable membrane underneath the soil and vegetation layer. The membrane can break (or become punctured), allowing water to infiltrate. What most often breaks the membrane are nails improperly and/or locked into the roof. Over time, for example, bamboo and wood can warp, and even if the nails are initially correctly, over time, the hammer-top of the nails can protrude out of the roof an through the membrane. One way to then protect the plastic from the nails is to put epoxy on the top of the nail after it is placed in the roof, locking it in place. Note that this process drastically increase the amount of work necessary to protect the plastic membrane from puncture.

5.1.2 Green wall

A.k.a., Green screen.

A green wall/screen serves a dual purpose as both a noise barrier and a runoff management system for water. Instead of directing this water into the sewer, the system guides the water toward a fence. There, the central material absorbs the water, which subsequently evaporates from the climate screen. The green screen is typically covered in cultivated vegetation.

5.1.3 Green building façades

A.k.a., Building façade vegetation, skyscraper green walls and green balconies.

Green building façade are where outdoor vegetation is placed around the facade of a building (including, roofs, balconies, walls, and other areas). This vegetation is considered part of the building's infrastructure and is maintained by building personnel and not the users of the building. These types of exterior building vegetation systems are not easy to maintain and require a lot of effort. In the early 21st century, as part of the "green" aesthetic, there are numerous rendered images on the internet of tall buildings covered in vegetation. Most vegetation covered buildings in these renders are actually, totally impractical, given early 21st century technologies. Imagine having to care for a large garden on the side of a tall building; it would require an unacceptable amount of work to maintain.

The following would need to be done to sustain and maintain such a system:

1. Design and then monitor the vegetation so that there is no possibility of:
   A. Root intrusion and membrane perforation.
   B. Falling hazards (particularly during storms). And, install and monitor falling nets.
2. Conduct regular maintenance operations:
   A. Maintain the system that transports large vegetation up a side of the building (e.g., crane).
   B. Replant vegetation as required.
   C. Replace vegetation and soil as required.
   D. Water (and, ensure regularly watering does not damage the building or waste water).
   E. Feed as required.
   F. Prune as required.
   G. Check for infestations and disease as required.

5.2 Gray infrastructural water units

A.k.a., Mineral-only water infrastructure, grey-water infrastructure, gray-water infrastructure.

There are several common ways to use "gray" infrastructure to channel water and facilitate drainage from architecture and landscapes:

1. **Drainage starts underground (underground water drainage):** The primary function of an underground drain is to collect and redirect excess water away from structures, basements, or areas prone to water accumulation. These drains can also facilitate infiltration and dispersion, and can reduce the waterlogging of soil. These drains have no visible surface drain (except for "clean-out" ports).
   A. **French drainage (a.k.a., underground permeable drain channel)** - consists of gravel and, on occasion, a perforated pipe to better channel water collected after infiltration into the ground. French drains are made by first digging the trench, then line it with permeable fabric to prevent roots from invading. Then install the pipe and gravel inside. French drains are deeper than trench drains, and it is this depth that allows them to redirect both ground and surface water. The gravel acts the same way as the grate in trench drains—filtering out debris to

prevent it from clogging the drain. French drains siphon water downhill to redirect it away from structures or pathways, but connecting them to a waterway is not necessary. The process of making a french drain is:

1. Trench excavation: A trench is dug in the desired location where water needs to be redirected or drained. The size and depth of the trench depend on the specific drainage needs and the amount of water to be managed.
2. Permeable fabric: To prevent roots and soil from infiltrating the drain, a permeable landscape fabric is often laid inside the trench. This fabric allows water to pass through while blocking debris and roots.
3. Gravel bed: A layer of coarse gravel is added to the bottom of the trench. The gravel serves multiple purposes, including providing drainage channels and acting as a filtration medium.
4. Perforated pipe (Optional): In some cases, a perforated pipe may be placed on top of the gravel bed. This pipe has small holes or perforations that allow water to enter and flow along its length.
5. Additional gravel: More gravel is added to cover the perforated pipe, creating a layer of drainage material.
6. Trench filling: The trench is then backfilled with soil or sod, depending on the surface where the French drain is installed. The drain is typically installed below ground level, allowing water to flow into it.

2. **Drainage starts at ground-level (ground-level water drainage):** The primary function of which is to efficiently collect and divert surface water, typically from paved or hardscaped areas, in order to prevent flooding, erosion, water buildup, and/or facilitate cleaning (as in a factory). These drains are typically not infiltration drains; instead, they are channelling/conduits to infiltration (or, storage). These drains can prevent flooding and help channel surface water.
   A. **Trench drains (a.k.a., channel drains, slot drains, strip drains, spot drains)** - long surface drains with long visible or hidden grates that allow water to pass into a below-surface long, trench-like channel that directs water. Trench drains are floor drains in the form of a trough with a slotted grate; they prevent any large objects from entering and blocking the drain. Trench drains are a surface water drainage solution, even though the components lay within the ground. The trough in the ground slopes downward to direct liquids and small debris into a catch basin, with a second strainer to catch larger objects. From there, the waste travels to a sewage system. Facilities that have high-capacity drainage or need to remove smaller solid objects. Unlike French drains, trench drains use quite a bit of material, including channels, end caps, outlets, grates, and catch basins. Trench drains are typically found outside, along pathways (e.g., driveway trench drains), in production buildings, and around pools. Trench drains are often used in high-traffic areas and industrial settings to handle large volumes of water and to prevent damage to the pavement.
      1. Covered trench drains. These drains can never get as large as uncovered tench drains (like large urban drainage ditches intended to capture large amounts of storm rainwater).
      2. Uncovered trench drains (a.k.a., drainage ditch) - are typically composed of concrete, and scale from small (e.g., two feet) to very large storm ditches.

   B. **Dry well drainage:** A dry well is a large vertical hole (void) in the ground, usually lined on the sides with concrete or brick for reinforcement. The well is open on the bottom, although some may have a layer of gravel or stone for added filtration. Dry wells are commonly connected to architectural stormwater run-off for infiltration (at the end of the well, where the water seeps into the ground via gravity). Other setups use French drains to direct runoff along the natural drainage path to the dry well. Dry wells can also be used to recycle “gray water” from sinks, tubs, showers, dishwashers, and washing machines. Dry wells should be placed in a low point of the yard, where the soil has a good infiltration rate, meaning that the ground absorbs water easily. Some soils, such as hard clay, are not suitable for dry wells, because the water could pool and take much longer to disappear into the ground. Accumulation of debris can be a problem, causing a dry well to lose its ability to absorb water quickly and overflow. Dry wells should be covered with a grate for safety and to minimize debris collection. They should also have a mechanism to handle overflow from extreme rainfall events, such as an exit pipe that connects to a storm sewer. Dry wells must be installed with a proper slope leading to them, so gravity will direct runoff toward them.

   C. **Catch basin drainage:** A catch basin is a drain device that catches water through a grate, collects the water and some debris, and then allows the water to flow out of the catchment cage into an outlet pipe, typically connected to a larger sewer network. The debris will often need to be cleaned out of the catchment basin cage as a regular form of maintenance. A catch basin drain differs from a dry well in that it directs water to drain pipes in a network. Water doesn't drain out the bottom into the soil, but exits via a pipe connecting to a storm sewer or other drainage area. Catch basins have grates on top to prevent them from collecting too much debris. Sediment and debris that makes it past the grate of a catch basin sinks to the bottom and stays there while the water rises to the exit pipe. Catch basins require regular cleaning to function properly and discourage pests. A typically underground sewer system in any urban environment has this structure -- catch basins are placed along the roadway path, and they collect water into a sewer network. Some sewer networks are large enough that humans can climb into them and walk through them. Others are not large enough for a human to crawl through. The sewers that are large enough for humans to walk through are accessed, typically, via "manhole" covers, which are circular (in shape) heavy ports positioned on the pathway itself that give access to the underground sewer network. Catch basins must be installed with a proper slope leading to them, so gravity will direct runoff toward them.

3. **Above-ground, architecture affixed water conduit drainage** (a.k.a., gutters).
   A. Gutter network on architecture redirects rainwater.

5.2.1 Permeable paver drainage

A.k.a., Porous pavement, permeable pavement.

Permeable pavers function to enhance infiltration, while maintaining an appropriate flooring surface. Permeable pavers rainwater to pass through the paved surface and into the underlying soil.

There are several types of permeable pavements (porous pavement).

1. **Permeable pavers (a.k.a., green pavers, turf pavers, green permeable pavers)** - pavers allow for the growth of grass or other vegetation within the paver structure, contributing to a green and eco-friendly landscape. These are the original and simple pavers with gaps within the pavers themselves and/or between pavers when placed in the ground. The gaps allow vegetation (preferablly ground vegetation such as grass or moss) to grow up between then, and water to flow down easily.
2. **Permeable interlocking concrete pavements (PICP; a.k.a., permeable pavement system)** are more complex permeable pavements with multiple layers and underground drains. PICP can provide 20 to 25 years of service when carefully constructed and maintained. The three types of pavers used in these systems are:
   A. Pavers that water will not drain directly through, but which channel water to surrounding joints, which contain porous, crushed aggregate.
   B. Pavers that allow water to drain directly through the paver object itself because it is highly porous.
3. **Permeable solid pavement systems.**
   A. Porous asphalt. Porous asphalt can have a life span beyond 20 years.
   B. Pervious concrete (a.k.a., porous concrete). Properly constructed parking areas utilizing pervious concrete will last 20 to 40 years.

Permeable interlocking paving systems involve a set of components that enable infiltration and precise channeling of water. When rainwater falls onto a permeable pavement surface, it is guided through the gaps between the pavers (and/or through directly permeable pavers themselves). Beneath is a "base" layer composed of a void space filled with compacted aggregate materials like gravel or sand, which acts as a filter, removing debris and pollutants from the water as it passes through. his layer provides structural support for the pavers and allows water to move freely within it. Underneath the base layer is typically an additional layer called a reservoir layer. This reservoir layer temporarily stores excess water during heavy rainfall events until it can properly infiltrate into the ground. The permeability a permeable paving system depends on various factors, such as: material composition, joint spacing, and overall design. Properly designed permeable paver systems can typically handle significant amounts of rainfall without causing standing water or run-off issues.

Permeable interlocking paving systems come with a host of benefits, but require more material. However, they typically have longer life-spans and require less maintenance than green infrastructure methods:

1. Good control: Permeable pavers can more precisely channel stormwater than other green infrastructure methods. The layering of the system gives the designer more options over control of the water.
2. Direct seepage: Permeable pavers help replenish underground water sources by allowing water to seep downward into the earth, and thus replenish

aquifers, rather than being lost as surface runoff. Traditional impervious surfaces, such as concrete or asphalt, prevent rainwater from seeping into the ground, leading to excessive runoff and increased flooding risks.
3. Reduced urban heat islands: Unlike asphalt or concrete, which absorb and radiate heat, porous paving materials help maintain cooler temperatures by evaporation and layering.
4. Visual appeal: Because of the layering of permeable paver system, they can be designed with a wide variety colours, shapes, and sizes available; they allow for creativity and customization. These pavers can be integrated into various settings.
5. Maintenance appeal: When appropriately used, permeable driveway pavers will crack and split less over time than concrete and asphalt surfaces. Resealing and patching are essential for asphalt surfaces.

Permeable interlocking paving systems may require maintenance, which typically involves vacuuming and washing out the system. Occasional vacuuming and power washing is required to remove debris.

Permeable interlocking paving systems are primarily designed with plastic in-earth inserts that provide structure and a basic order and separation to the system. They involve a plastic ring-on-grid structure designed to go on/in the earth and support an upper surface layer (of tile, grass, etc.). Around the ring-on-grid structure is typically placed gravel (as the top-layer, or before tile-pavers) or earth (for a top-layer of grass). In a general sense, it could be said there are three arrangements of the plastic earth-insert:

1. A gravel paved system for tile-pavers; where the tile-pavers are surrounded by gravel and/or placed above a gravel layer).
2. An earth paved system for grass and/or tile-pavers; where the tile-pavers are surrounded by earth and grass.

6 Pond-water units and processes

A pond is a water storage basin. Ponds are designed to hold some volume of water for some duration of time. Ponds that are not sealed or lined in some way will seep water into the ground.

6.1 Pond construction

There are several optimal places to construct ponds on a landscape (based on slope, and relating to storage efficiency):

1. A pond(s) may be constructed at the high point of the slope (top of the hill). This pond may be filled with rainwater or pumped with water. This pond is usually shaded with surrounding trees. The higher up in the landscape water can be stored, the greater the potential for using that water anywhere using gravity (and not electricity).
2. As the surveyor goes down the slope, the ponds go from steeper, short and shallow to more gentle and elongated. Typically, there are much better soils for building ponds lower down in the landscape.
3. Ponds may be placed in valleys (where there is greater water concentration), or on ridges, or elsewhere.
4. Ponds need to be planned with spillways to handle large and historic levels of flood events. The size of the spillway needs to be related to the amount of water flowing into the dam (pond) during flood events. A wide channel that allows water to flow around the dam. However, it is best to put a triple-pipe at a slightly lower elevation than the spillway, to pipe rising water down beneath the pond's dam. With both systems, most of the time, the spillway should not have water flowing through it; only in major flood situations when the triple pipe is overwhelmed. Culverts at the back of the pond might be used to discharge the pond to some relative degree. These culverts can have hydro-power generators attached to them. These culverts should not be used for flood events. Ponds can also be connected with a swale and berm, so that when one pond overflows and water enters the spillway, the spillway then channels water to another [overflow] pond.
5. Water should never slosh over the top of the dam, thus causing erosion.
6. A clay core and key trench may need to be put created inside the dam wall to ensure that water doesn't seep into the wall, eroding it, and causing a failure of the dam wall.
7. The placement of trees and other woody perennials on the dams of ponds on slope should be carefully

considered, because the tree roots can work their way through the pond and create pathways for water to leak through.

There are several ways to seal ponds, including:

1. If there is enough clay content in the soil, then a natural pond might form.
2. If the water table is high, there might be a pond in the presence of a basin.
3. Ponds can be made and sealed with compacted clay or an impermeable membrane.
4. Clay ponds can be made more water proof through the droppings of ducks and other animals. In other words, ducks on a clay bottom pond lake will help to natural seal leaks with their fecal droppings over time.

6.2 Types of ponds by function

There are many practical uses for a pond. The following are a list of potential functions for ponds in a pond system/network:

> **NOTE:** *Ponds cannot be discharged for aesthetic reasons.*

1. **Porous ponds (a.k.a., unlined ponds, seepage ponds, swale and berm ponds)** - allow water to seep down into the water table. These "ponds" are designed to slow and catch water, and slowly drain it into the ground. They are essentially water slowage and seeping ponds. These ponds seep water into the landscape where it is retained. Clay compacted ponds will seep water into the landscape.
2. **Non-porous ponds (a.k.a., impermeable membrane lined pond)** - will not allow water to seep down into the water table. The ponds retain water on the landscape.
3. **Waste treatment ponds (a.k.a., waste stabilization ponds)** - allow the safe cycling of waste water.
4. **Evaporation ponds** - allow the surface water to evaporate by sunlight and exposure to the ambient temperatures. Evaporation ponds have several uses. They can be used to evaporate stormwater. Evaporation ponds can have lids put over them to collect water through the processes of evaporation and condensation. Evaporation ponds are also used to dispose of brine from desalination plants. Mines use evaporation ponds to separate ore from water. Evaporation ponds at contaminated sites remove the water from hazardous waste, which greatly reduces its weight and volume and allows the waste to be more easily transported, treated and stored. Evaporation ponds can be used to produce salt and mineral solutions from sea water (i.e., salt evaporation ponds). However, any contaminants in the seawater will end up resulting solution. The evaporation of water leaves most, but not all, salts and impurities behind. In the agricultural industry, evaporation ponds are used to prevent pesticides, fertilizers and salts from agricultural wastewater from contaminating the water bodies they would flow into.
5. **Human use ponds** - store and supply water for later human usage. Human use ponds should be sealed as well as possible to save water.
6. **Irrigation ponds** - store and supply water for later usage in irrigation. These ponds can be filled via rainwater or via a water distribution network (gravity- and/or pump-fed). Irrigation ponds should be sealed as well as possible to save water. Irrigation ponds are themselves distributed into an irrigation network. This is achieved either with a lock-valve pipe going through the dam wall of the pond, or a pressurized siphon that brings the water up and out of the pond. A rain-fed irrigation pond may be empty by the end of the dry season.
7. **Current regulation ponds (a.k.a., stream control ponds)** - are ponds used to regulate the flow of streams of water along the landscape.
8. **Drainage ponds** and **retention basins (a.k.a., storm drainage ponds)** - are used for detention/retention/evaporation of storm and flood water. Storm drainage ponds are part of the overall surface water management system on a site and are used for flood control. The purpose is to store water during peak storm events to slow the discharge offsite and contribute to the flood control of a local storm area. There are two basic types of storage: an above ground pond or underground structures of vaults or high-volume pipes. Ponds generally have an“outflow structure” composed of an inlet and a metered outflow structure. Surface ponds are usually planted with vegetation that serves as a pollutant filter of water before being discharged downstream.
9. **Recreation ponds (a.k.a., swimming ponds)** are used for human bathing, swimming, and other recreational activities. Recreation ponds should be filled with sufficient water all year. Generally, these ponds should have a gradual slope so people can get in and out safely.
10. **Fire-fighting ponds** - these ponds are used for fighting fires and should be full throughout the dry season. These are generally high-volume, non-electric release. They are typically positioned high on the landscape so gravity can provide enough

pressure (because generally during a fire there is no electricity).

11. **Natural pond (a.k.a., ecological cultivation ponds)** - a pond to provide at least a natural ecological environment for diverse plant and animal species. There are three general types of natural ponds: wild ponds outside of the perimeter of the city, natural cultivation ponds inside cities, and natural recreation ponds inside cities. In natural cultivation ponds, a variety of organisms can be harvested from these ponds, including birds, fish, crustaceans, and aquatic plants. Humans can swim in natural swimming ponds. In some cultivation ponds, ducks act as aquatic filter feeders and will filter the pond as they grow themselves.
12. **Aquaculture pond** - A pond where the inflow and outflow of water are controlled and maintained to sustain the water level, nutrient level, and sustain the harvest of the species being raised/cultivated (e.g., trout, algae, etc.). The outflow effluent of an aquaculture pond may be usable as a fertigation (fertilization and irrigation) water source for crops.

Notes on pond multi-functioning:

1. There is typically not one pond, but a pond network.
2. Some ponds have a continual water source, and others depend on rainfall.
3. A recreational pond can also be a firefighting pond, because both of these uses require that water is maintained throughout the year.
4. A fire-fighting pond cannot also be an irrigation pond, because the irrigation pond will be emptied during the dry season as water is applied to crops (if rain-fed).
5. A habitat pond can seep (or not). If it seeps, it may benefit the hydrology of the local area. Seepage is not advisable on all landscapes.

Besides water transformation, ponds provide a number of other benefits:

> **NOTE:** *Ponds do not function well on sandy or other highly porous soils*

1. Ponds are often used for frost protection, particularly on wine grapes. The use of water for this purpose typically ranges from 0.4-1.6 inches of water in a year.
2. Ponds can be managed to provide wildlife habitat.
3. Ponds constructed primarily for fish production, typically at least a half-acre in size and a minimum depth of 8 feet, can yield 100-300 pounds of fish per year for each acre of water surface.
4. Ponds can assist in flood control by capturing and slowing the flow of water through a watershed.
5. Ponds help recharge groundwater. Whether filled with water diverted from a stream or with tailwater from irrigation, clay-lined ponds seep water into the ground at highly variable rates (depending on size and construction), but typical seepage loss from a well-sealed pond is estimated at one foot of water per year.
6. Storing water captured from rainfall or from tailwater in on-farm ponds can also reduce energy use by displacing pumped groundwater.
7. Ponds can serve as water sources for fire protection if they are sited in proximity to structures.
8. Ponds can be used to settle and filter runoff, capturing soil that can be returned to use and filtering pollutants and particulates that would otherwise negatively impact the broader ecosystem.
9. A pond network creates a more localized and distributed water supply, which can offset water transported from distant reservoirs, reducing the energy needed for water conveyance.
10. Ponds can be used in the intentional and directed flooding application known as rapid flood flow irrigation. Rapid flood flow irrigation involves the application of a large amount of water to the land, which soaks in, and does not have significant evaporation.

6.3 Natural swimming ponds

> *A.k.a., Natural swimming pools, natural recreation pools.*

A natural swimming pool or natural swimming pond (NSP) is a system consisting of a constructed body of water, where the water is contained by an isolating membrane or membranes, in which no chemicals or devices that disinfect or sterilize water are used, and all clarifying and purifying of the water is achieved through biological filters and plants rooted hydroponically in the system.

It is called a “natural swimming pool” because the filtration systems used have biological equivalents in the natural world. In fact if there is not an example of the type of filtration being used in the natural world then it is not seen by the IOB (International Organization for natural Bathing waters) to be naturally filtered. Natural aquarium and koi ponds also exist, but use algae scrubbers for their filtration. Systems that use UV, ozone and copper/silver ion disinfection techniques are examples of additive methods.

The NSP is divided into two areas, the swimming zone and the regeneration zone, which are physically separated. The regeneration zone and swimming zone must be equal in area for sufficient purification. The swimming portion of the pool can look like a conventional swimming pool or a natural pond. The regeneration zone and swimming zone must be equal in area for sufficient purification. The swimming portion of the pool can look like a conventional swimming pool or a natural pond. The regeneration zone can be placed adjacent to the swimming area or in a remote location depending on the space available. In up-to-date natural swimming pools there is no minimum depth for the swimming zone and the regeneration zone can now be reduced greatly and in some cases is non existent.

NSPs rely on a combination of hydraulic design techniques in conjunction with a fine filter. They require a specialized skimmer or overflow channel. Downstream, a bioreactive biological filter removes and retains additional particulate matter down to a particle size of 100 micrometres. Pumps different from those found in conventional pools hydraulically optimize water flow rates and volumes, thereby accelerating the cleaning process even further. This mechanically enhanced natural filtration produces clear, clean water. In fact, when NSPs are installed in Europe, pool owners and builders will ceremoniously wrap up an installation with a ceremonial drink of water collected directly from the pool. A biofermenta system is the latest form of filtration for NSPs reducing the need for large plantation areas and filtration beds.

In an NSP, swimming pool water flows via gravity from the swimming pool into distribution shafts. The water then passes through a biological fine filter/bioreactor before it is pumped into the regeneration zone. Plants in the regeneration zone are planted in the substrate, and these plants compete for nutrients that would feed algae. The water is cleaned biologically by the metabolic processes found in the substrate in which the plants are rooted. Thus, microorganisms and the water plants ensure effective, continuous cleaning. No processes beyond these, such as UV sterilization, are necessary unless something is added into the system that causes an imbalance.

Because of their reliance on natural environmental factors, each NSP system is built with consideration to the region and climate where it is installed. Construction elements such as the biological filter and the combination of contaminant ridding plants vary with each pool. These ponds may also be connected to a larger pond water filtration, purification, and recycling system.

Of note, natural swimming ponds can be heated to 27°c, and under certain circumstances, higher than that. These ponds do require some additional pipework and a heating system. Once people become acclimated to swimming in a pond, temperature is often not found to be the issue they thought it was beforehand. Particularly for natural designs, water in the shallow areas heats up quickly in the sun and can raise the natural temperature of the whole pond to 75 degrees during the summer in some climates. Heat pumps and solar panel warming systems can easily be incorporated into NSP construction.

Perhaps more importantly, natural water "feels" much more comfortable on the skin. It has a different composition of suspended and dissolved solids, and so, what might feel cold in chlorinated water, 71 degrees for example, actually feels comfortable in natural water.

Typically, a chemically treated pool can discharge up to 3 times its volume of water into the sewer per year. As there is no use of chemicals in the water of NSPs and their water is maintained as "living" (i.e. the NSP is not drained and refilled), there is no need for this waste of water being discharged into the sewer. Also, there is considerably reduced energy consumption for the mechanical operation of many NSP systems.

Each NSP is unique, and so each has a different "break-in" period during which the system finds balance. While NSPs can be used for swimming immediately, it takes approximately two to three years until a stable biological equilibrium is reached. Once an NSP has reached equilibrium, it requires considerably less regular maintenance than a conventional swimming pool. Seasonal care and maintenance is still required over the course of the year, though even this differs from care of a conventional swimming pool. For example, ducks and other water fowl in migration have been known to visit NSPs during the winter months. Additionally, amphibious and aquatic creatures like frogs, salamanders, and snails often make their homes in the regeneration zones of NSPs.

7 Waste-water units and processes

A.k.a., Waste-water treatment, water sanitation cycling.

All drains post human and/or machine use lead to some sort of waste-water treatment network. Waste-water is otherwise known as sewage water, sewer water, sanitary water, drainage effluent, etc. Waste-water is essentially, anything that can be put down any drain and mixed with water.

Waste-water can be composed of any combination of the following (Paulo, 2018):

1. Water.
2. Feces - contain organic matter, nutrients and various organisms potentially transmitting diseases, such as bacteria, viruses, worms, and blood. These pathogens can be eliminated over time through dehydration, composting, digestion, and filtration. There are thermo-tolerant coliforms present in the large intestines of warm-blooded animals, including humans, and these can cause illness. All effluents containing feces must be treated in systems isolated from contact with the supply of water to food, edible plants, animals and other humans. However, plants that grow in treatment systems of sewers can have leaves and fruits consumed normally, due to the fact that the bacteria are not absorbed by the roots, and do not contaminate other parts of the plant. Note here that splashing should be considered in relation to bacterial contamination.
3. Urine - contains nutrients that are important for plants (mainly nitrogen and phosphorus). However, its addition to plant soil should be done with intelligence. Urine rarely contains disease-causing organisms; but it can sometimes contain disease-causing organisms. Urine generally contains human hormone residue. Urine will contain by-products of medications.
4. Blood, skin, and other tissues.
5. Fibers:
   A. Sanitary paper.
   B. Clothing.
   C. Hair (natural fibers). Natural textile fibers and hair are relatively inert in the environment and do not cause pollution or contamination, although a build-up of hair can easily cause blockages. In particular, hair can cause blockages when drains output into a plant root system or water is directly re-used in the irrigation system. In these cases, filters should be placed on the system to filter out this material.
   D. Synthetic fibers.
   E. Plant fibers.
6. Other organic matter (e.g., food). This organic matter is composed of some combination of carbon, hydrogen, oxygen, nitrogen, sulfur, amongst other elements.
   A. Food.
   B. Skin and hair (fiber), and nails.
7. Nutrient compounds: such as nitrogen, phosphorus, and potassium.
8. Lipids (i.e., fats) - are a type of organic material that is more difficult to decompose. Fats can easily cause clogging, reducing water infiltration into the soil and harming aquatic life in particular. Lipids can be separated by a floatation process (in a fat/lipid/grease filter box), or by organic matter filters (e.g., fibrous-root plant transpiration evaporation circle such as a banana transpiration and evaporation circle. Note: A fibrous root system is the opposite of a taproot system.).
9. Soaps and cleaning chemicals - these are considered pollutants with varying degrees of biodegradability, particularly in aquatic environments. Less harmful when placed in non-aquatic environments.
10. Manufacturing and manufactured chemical - these include all manner of chemicals used in the home, in offices, in municipalities, and in manufacturing/production facilities. These tend to be the most toxic and least biodegradable. These include poisons, fuels, dyes, heavy metals, detergents, lubricants, synthetic intermediary chemicals, synthetic textiles, etc.

There are three principle characteristics of waste in water:

1. **Bio-degradability** - substances that will break-down quickly. If it is not bio-degradable, then it will not break-down quickly. There are pollutants that can be broken down by ecological systems.
2. **Bio-compatibiiity** - substances that will break-down into other substances that are beneficial for plant growth. If it is not biocompatible, then it will not break-down into substances beneficial for plants, and likely break down into substances harmful to the ecology. There are pollutants that can be broken down into biocompatible substances, or at least absorbed and stored without harm.
3. **Persistence** - substances that will persist in the environment and not break-down easily. Greater persistence means the greater the likelihood for downstream effects over time. Metals are naturally

persistent.

Some soaps and detergents specify that they are grey water safe. Simple natural soaps and detergents are grey water safe.

The outputs of a waste processing system for human and other organisms is:

1. Food, as feed, for other animals (e.g., kitchen scraps for chickens and pigs).
2. Evaporation of water into atmosphere.
3. Transpiration of plants up-taking water and respiring it in the atmosphere.
4. Fertilizer, nutrition (e.g., direct application of urine, or mixing into solution, for application).
5. Extraction of chemicals (e.g., from urine).
6. Infiltration into the soil and aquifers.

A waste-water solution can be broken down at a high-level into three elements:

1. **Liquids** - are the liquid part of the mixture.
2. **Solids** - are agglomerations of physical elements, and are not the liquid part.
3. **Sludge** - are the solids that settle at the bottom of the tanks and reactors. Consist of microorganisms and decomposing organics. Sludge occurs in storage tanks, as well as septic tanks and reactors.

Sewage (waste sanitation outputs) can be categorized into three general sources (i.e., there are several types of sewage):

1. **Domestic sewage (a.k.a., urban sewage, sewage, black water)** - is wastewater that comes from domestic activities. That includes houses, public toilets, restaurants, schools, hotels and hospitals.
   A. Optimally, domestic water should be treated sufficiently before release into the ground, a water body, or re-use.
2. **Industrial sewage (a.k.a., chemical sewage, sewage, black water)** - is wastewater that comes from industrial activities (including production and mining) or the very usage of industrial chemicals in domestic/urban settings.
   A. Optimally, industrial water should be treated sufficiently before release into the ground, a water body, or re-use.
3. **Rainwater sewage (a.k.a., stormwater sewage, non-sewage rainwater, green water, green water sewage)** - is water that comes from drains that take in rainwater. This includes rainwater and stormwater from flooding. It also includes anything caught up in rainwater and in flooding.
   A. Optimally, rainwater should flow to a water body.
   B. Rainwater channels may need filters to collect trash out of the water.

It is important to note here, that it is always best to separate these system systems in the habitat. In some locations on the planet, these sewer systems are separated. In other places they are not. In a combined (conventional) sewer system, stormwater runoff is combined in a single pipe with wastewater from homes, businesses, and industry. During drier weather, the stormwater and wastewater are carried to the sewage treatment plant together. But ever more frequent torrential rainfalls and high volumes of stormwater can exceed the capacity of a combined sewer system. It is always advisable not to allow rainwater or drained rainwater into a domestic or industrial sewer network. There are two ways rainwater can get into non-rainwater sewers: Infiltration via breakages; and, Inflow via someone rigging a downpipe into the sewer (a pipe that is not supposed to be their by habitat master plan and protocol).

Human bodily outputs include (Esrey et al., 1999):

1. Human excreta:
   A. The total amount of faeces excreted by a human being along one year approximately ranges from 25 to 50 kg, containing on average approximately 550 g of nitrogen, 180 g of phosphorus and 370 g of potassium.
   B. Most part of nutrients contained in human excreta comes from the urine. An adult can produce approximately 400 L of urine per year, containing approximately 4 kg of nitrogen, 400 g of phosphorus and 900 g of potassium, easily absorbed by plants.
2. Human tissue: skin, nails, and hair.

7.1 Waste sanitation treatment solutions

The phases of the waste treatment process may be seen as:

1. Reception.
   A. Liquid.
   B. Dry.
2. Separation of types of waste.
   A. Solids
   B. Fats.
   C. Etc.
3. Digestion of organic matter.
   A. Water digestion.
   B. Underground digestion.
   C. Above ground digestion.
4. Filtration.
   A. Micro-ecology.

5. Absorption.
   A. Plants.
6. Infiltration.
   A. Soil.

Sanitation treatment solutions include three general categories:

1. **Sewage treatment in air:**
   A. Evapo-transpiration:
      1. Evaporation - of water on and/or in surfaces, into the atmosphere.
      2. Transpiration - of water through plants, into the atmosphere.
   B. Compost - above ground compost piles.
2. **Solid sewage treatment underground:**
   A. Compost - below ground compost pits.
   B. Land fill pits - that accept "trash". These large pits are lined to prevent leakage into ground water, but are often found to be leaking. These pits also produce gas that can be collected and harvested for fuel and other usages.
3. **Sewage treatment in water:**
   A. Anaerobic reactions:
      1. Septic tank and reactors where anaerobes and other microbes digest organic matter resulting in soluble nutrients and gasses, such as hydrogen sulfide, carbon dioxide, and methane. Waste-water is typically put into either a septic system, or a municipal system that acts similarly. The water first goes through anaerobic reactions, it is digested by microorganisms resulting in soluble nutrients and gases, such as hydrogen sulfide, carbon dioxide, and methane. These systems produce sludge.
      2. Sludge removal:
         i. In systems that receive only water and organic materials, the system can be designed so that decomposition happens at an optimal rate, reducing the need for withdrawal operations.
         ii. In systems receiving large amounts of chemicals and solid particles, such as fibers, soil and hair, the volume of sludge tends to increase and will need to be removed periodically.
         iii. Note: It is important to always keep some of the sludge in the system because it harbors microorganisms that promote decomposition of the matter they are likely to receive.
      3. Fuel gas can be produced as methane from the biodigester. However, domestic sewage does not have great potential for gas production in a biodigester. However, it can be mixed with animal manure to create a compatible production environment to produce enough gas for the human dwelling usage.
   B. Aerobic reactions:
      1. The decomposition of organic matter in aerobic environments (in the presence of air) produces CO_2 and organic matter stabilized in the form of humus, which may be used as a soil conditioner/fertilizer. It does not produce slurry or methane. (Paulo, 2018)

Treatment systems that digest organic matter may reduce the presence of pathogens in the effluent, but may not completely eliminate it. For this reason, reactor effluents and anaerobic filters, must be used with care. If they are used for fertigation (fertilized irrigation), the system must be dripped or through subsurface perforated pipes, so as not spray the liquid over the landscape. (Paulo, 2018)

In addition, parasite eggs (e.g., helminth eggs) can be transmitted when body parts or food come into contact. Systems of black water treatment, which may use some type of filtration (to retain eggs and larvae) or chemical introduction before the final effluent treatment system. Waste from dehydration or composting (e.g., dry toilets), will need at least 6 months (or more) of rest and decomposition for these eggs to become inactive. (Paulo, 2018)

The treatment of effluent may go through the following phases (different types of effluent may/will go through different processes):

1. Monitoring.
2. Transportation.
3. Storage (storing, retention).
4. Infiltration into the soil.
5. Separation of different types of material.
6. Digestion (decomposition, use of nutrients and pathogen reduction).
7. Dilution is the addition of more water.
8. Chemicalization (addition of chemicals).
9. Evaporation of water into atmosphere.
10. Transpiration of plants up-taking water and respiring it in the atmosphere.
11. Transpiration-evaporation (evapo-transpiration).
12. Absorption of chemicals (e.g., metals)
13. Nutrition, fertilizer (use of nutrients by plants and animals, including micro-organisms).
14. Re-use, residue collection, or final destination.
15. Biomass compost.

7.1.1 Water recycling considerations

If the soil is overly permeable or not permeable enough, or there is not enough area to effectively process the water, recycling may not be practical. If the system is in a cold climate, recycling for irrigation may only be possible during the warmer months. Some jurisdictions have certain restrictions against the use of greywater systems and other ecologically-based solutions.

7.2 Dry waste systems and compost

I.e. Human waste collection systems that do not use water

A dry toilet is a toilet that operates without flushwater. Human waste is mixed with drying material. The mixture is then transported to a composting location. Dry waste systems are typically composted via a variety of compost techniques. Faecal matter can be mixed with dry matter and composted. It doesn't matter if urine is or is not mixed in. With each use, faeces are covered with a mixture of drying materials, especially sawdust.

There are many different types of dry toilets, which can range from a simple bucket to a structural chamber designed to receive the waste and vent appropriately. In the case of a chamber, air circulation in the chamber promotes the material dehydration and pathogen neutralization. The operation of these systems requires that the dry waste matter in a bucket or chamber be transported to a separate compost location at some regular interval.

There are waste systems without the regular use of water for the operating of the system (it should be noted, however, that for maintenance, water is often required:

1. Dry systems without separation.
   A. E.g., Dry toilet without urine diversion - contains feces, urine, and possibly, drying material (i.e., toilet paper and other materials to dry the mixture, including earth, ash, lime, sawdust, which may be used separately or combined).
2. Dry systems with separation.
   A. Dry toilet with urine diversion - contains feces, and possibly, drying material (i.e., toilet paper and other materials to dry the mixture, including earth, ash, lime, sawdust, which may be used separately or combined).
   B. Dry urinals without automatic/manual user water flushing - produce urine without the users' use of water. Can be made for both men and women. Can be simple or more complex systems. Urine is stored in a trap, and some may go down a waste drain. These urinals are often called waterless urinals. These urinals require more regular cleaning than water-based urinals. These urinals require proper usage. These urinals require the removal, cleaning, and replacement of the urine trap. These urinals still require water to clean, but use less water overall. These urinals must be wiped down regularly. These units often have problems with odor, and can have problems with overflow. These units sometimes use the addition of chemicals regularly added to create temporary odor barriers. These types of urinals are not permitted in some jurisdictions. The collected urine may be used as fertilizer or added to grey water.

7.3 Wastewater receivers (a.k.a., drains)

Wastewater receivers (a.k.k.a., drains) are of three types, and are named after their source:

1. Domestic drains.
2. Industrial drains.
3. Rainwater (stormwater) drains.

Wastewater drains may go to any of the following:

1. Water bodies (for dilution and re-climactic water cycling).
2. Filters and traps (for collecting and purifying).
3. Gardens (for infiltration and irrigation).
4. Ecological water processing network (for purifying).
5. Industrial (using many ecological principles) water processing network (for purifying).

7.3.2 Black water treatment

A.k.a., Digestion of organic material with pathogens, dirty water, pathogenic water, toxic chemical water.

Blackwater ecological treatment uses a variety of technologies for the digestion of organic sanitary/waste materials and the cleaning of water:

1. **On-site sewage systems** (a.k.a., decentralized wastewater treatment systems, DEWATS) that do not allow separation can either break waste (in water) down using oxygen (aerobically) or without oxygen (anaerobically); typically black water is treated anaerobically first, then aerobically second:
   A. **Anaerobic waste treatment system** (a.k.a., anaerobic tank, septic tank, digestion tank without oxygen, bioreactor septic tank, anaerobic reactor on a septic tank system, anaerobic digester, anaerobic filter) - are based on the combination of a physical treatment (settling) and a biological treatment without oxygen. Anaerobic systems may be operated in an upflow or downflow mode. Anaerobic

digestors are a type of waste treatment system that converts organic waste (only) into biogas and digestate. Biogas is a renewable resource that can be used to generate electricity or heat through combustion. Digestate is a nutrient-rich fertilizer that can be used to improve soil quality. Anaerobic digestors are a slow process. It can take several months to convert organic waste into biogas and digestate, with sufficient material and good conditions.

B. **Aerobic waste treatment system** (a.k.a., aerobic digester, aerobic treatment system, aerobic filter) - is used as a secondary treatment step in blackwater and greywater treatment; after the black water goes through an anaerobic system.

Two most common ways of processing blackwater are:

1. **Water cycling waste stabilization ponds:** An ecological wastewater purification pond network where there are anaerobic and aerobic ponds and layers within. These ponds cultivate a variety of plants that facilitate the appropriate processing of water in that pond.
2. **Tank and pond waste stabilization:** A combination tank and pond network where anaerobic and aerobic systems process and stabilize waste. The general process is as follows:
   A. Wastewater flows into a settling septic tank where all solids settle as sludge that will be decomposed by microorganisms.
   B. The solid waste from this tank is eventually sucked out by a septic pumping service that transports the waste to another, larger treatment facility.
   C. The flow equalization tank evenly releases water to the next step in the process, balancing out the surges from periodic overuse of the facilities.
   D. Effluent water from the anaerobic tank(s) is pumped into the aerobic wetland cell where plants and microorganisms feed on it, reducing pollutants and removing odorous gases, with only partial volume loss through evaporation and transpiration.
   E. A level adjust basin controls the amount of water contained in the wetland cell (a.k.a., aerobic system).
   F. A biofilter in the trickling irrigation system removes compounds and elements (e.g., ammonia, phosphorus, nitrogen, etc.) and is connected to the level adjust basin and flow equalization tank.

Note: This system would need electricity to operate unless it is on a descending hill. In colder weather, tanks would need insulation. And, pipes leaving the house need a backflow preventer.

7.3.1 Anaerobic tank treatment (a.k.a., septic tank)

An anaerobic (septic) tank is a small sewage treatment container that mainly collects the waste-water, separates it into layers, and has anaerobic biological activity. The septic tank is a buried, water-tight container usually made of concrete, fiberglass, or polyethylene, with an inlet and an outlet. Septic tanks hold the wastewater long enough to allow solids to settle down to the bottom forming sludge, while the oil and grease floats to the top as scum. A plat baffle or siphon prevents the sum from exiting into the effluent. The wastewater travels through a filtering system and is partially processed by bacteria. Wastewater is fed to the tanks (usually via gravity, and/or by a pump), which is why septic tanks are usually placed underground. The longevity of a septic system is directly linked to proper maintenance and the amount and strength of waster-water into the system. The purpose of the septic system is to separate the waste-water into three separate layers. It is intended to trap the solids and greases (lipids) inside the tank, and only allowing the liquid effluent to leave the tank. If the tank doesn't settle out into three layers, then there is something wrong with the system itself, or a user error. The top layer is the scum layer and is made up of lipids (a.k.a., fats, oils, and greases). The middle layer is the liquid effluent layer. The tank is designed to allow only this water to exit the tank. The sludge layer accumulates on the bottom of the tank.

There are many different configurations of anaerobic tank treatment:

1. Compartments - all septic tanks have internally separated compartments. Most septic tanks are separated into two compartments. However, there are septic tanks with more than two compartments. To prevent sum coming out of the output of each chamber, each output to the next chamber (or to the outside) must be located a little below the liquid surface.
   A. Two-compartment septic tank - is the original and most common type.
   B. Three- to five-compartment septic tank (3 to 5 upflow chamber septic tank) - is an improved septic tank with a series of upflow chambers, which increase the efficiency of treatment. It can treat a wide range of wastewater, but the sludge and effluents still need additional treatment material to be reused or disposed of properly. In this system, most settleable solids are held in the first chamber, followed up by three or more additional chambers.

2. The three layers of substance in the tank (optimally):
   A. A layer of fats called scum, which floats on the surface of the liquid waste. The scum (or layer of fats) helps prevent odours and air entering the ecosystem. This top layer of sludge must be removed periodically so as to not compromise the functioning of the system.
   B. A layer of liquid waste called effluent.
   C. A layer of solids called sludge, which sinks to the bottom. This bottom layer of sludge must be removed periodically so as to not compromise the functioning of the system.
3. Inputs:
   A. Black water, brown water, grey water, outputs of the fat box filter, etc.
4. Process:
   A. The processes involved in a septic tank are:
      1. Retention to sedimentation of solid particles and floatation of lipids, thus creating a three layer system (with effluent as the third layer).
      2. Biological anaerobic digestion of organic material with bacteria and enzymes. This digestion converts solids to liquids. Septic tanks work by allowing wastewater to sit and undergo a settling and digestion process. Septic tank sewage is decomposed by bacteria, making it easier to transfer.
5. Outputs:
   A. Effluent - contains a wide variety of pollutants including pathogens, faecal bacteria, phosphorus (P), nitrogen (N), organic matter (OM), suspended solids (SS), pharmaceutical compounds and household detergents and chemicals that pose risks to fresh water resources. It must be forwarded to post-treatment at a root zone, anaerobic filter, filtration ditch, or to the sewage collection network.
   B. Sludge - sedimented solids.
   C. Lipids (a.k.a., fat, grease, oils) - lipid separation, or not.
   D. Biogas - Gas collection, or not.
      1. During anaerobic digestion, biogas is produced in small volumes, which can be stored and used. If the gas is not recovered, then the tank needs to be ventilated to avoid the concentration of harmful gases with fuel potential. Pressure buildup in the tank can be dangerous. If a septic tank has inlets and outlets, they must be vented, unless the gas is to be collected. There is a greater possibility for biogas collection from a septic tank with more than two compartments.
6. Monitoring and maintaining:
   A. It is important to monitor and remove sludge and scum to maintain proper functioning. The amount of sludge in the tank should be measured regularly with a core sampler (a tube that is stuck into the tank to collect and measure the sludge amount). When the core sampler is pulled out the user has a cross-sectional view of the septic tank. These tanks should normally be pumped out when the scum and sludge layer, together, equal 25-30% of the liquid depth of the tank. If the tank is never pumped, the sludge and scum layers will build up to unhealthy levels and eventually clog the system, but not before contaminating downstream systems.
   B. Dwelling septic tanks are typically pumped every two to five years. Alternative systems with electrical float switches, pumps, or mechanical components should be inspected more often, generally once a year. To pump the system a vacuumed hose is inserted into the septic tanks holding area. When the nozzle of the vacuum is submerged in the waste the pump is activated to increase pressure forcing the waste to rise up the pipe and begin filling the waste removal tank.
7. Installation:
   A. There are required separation distances between architecture, wells, and a septic tank.
   B. Tanks may contain an aerator.
   C. Tanks have special bacteria added to them to facilitate healthy anaerobic decomposition.
   D. It is often best to have the top outermost lid of the system visible above ground level, and for the material surrounding the lid in the area where the tank is placed in the soil/ground to be covered by gravel. Hence, to access the lid, you have to walk over gravel, and the lid is visible and positioned above the gravel.
   E. A trash tank is similar to a septic tank in design and is generally used before advanced treatment units (ATU).
8. Risks:
   A. Never put oil, gasoline, paint thinners, paint, solvents, photographic chemicals, disinfectants. weed or insect killers down the drain. They can poison the septic system and possibly threaten water supplies for the whole neighbourhood. Even some soaps and detergents can harm the healthy operation of the septic tank.
   B. Septic tanks can lead to increased soil and groundwater contamination when effluent discharges. (Anil, 2016)
9. Code:

A. Brazil: NBR7229 / 1993 and NBR 13969/1997

There are a many different configuration of anaerobic waste-water tank treatment system, including but not limited to:

1. **Down-flow anaerobic tank treatment system** - aims at settling solids and treating water with anaerobic digestion. It comprises a watertight tank containing only water and no layers of submerged media. The water contains anaerobic bacteria. As the wastewater flows through the tank from top-to just under the top layer, it outputs cleaner, though still potentially pathogenic effluent.
   A. Inputs:
      1. Blackwater, greywater, brown water, faecal sludge, or effluent from pre-treatment system.
   B. Process:
      1. A biological reactor where sludge settles to the bottom, lipids to the top, and anaerobic microbes break down the biomass.
   C. Outputs:
      1. Sludge, effluent, vented gas.
2. **Up-flow anaerobic filter system (a.k.a., upflow anaerobic filter process, UAFP)** - aims at removing non-settleable and dissolved solids. It comprises a watertight tank containing layers of submerged media. The media provide surface area for bacteria. As the wastewater flows through the filter usually from bottom to top (up-flow), it comes into contact with the biomass media in the filter and is subjected to anaerobic degradation (Morel, 2006).
   A. Inputs:
      1. Blackwater, greywater, brown water, faecal sludge, or effluent from pre-treatment system.
   B. Process:
      1. A biological reactor with effluent in ascending flow, composed of an empty lower chamber and additional chambers filled with submerged filter medium, that act as an anaerobic microorganisms responsible for stabilization of organic matter.
   C. Outputs:
      1. Effluent, vented gas.
3. **Biodigester septic tank (a.k.a., biodigester)** - are designed to anaerobically decompose organic matter via bacterial digestion to produce biogas and biofertilizer.
   A. Versions:
      1. A three tank compartment system where three collection boxes are buried in the ground and interconnected by PVC pipes and connections
   B. Inputs:
      1. Blackwater, brown water, manure.
      2. Black water, brown water.
      3. Fresh manure and organic waste.
      4. Note, these systems do not work with gray water.
   C. Process:
      1. Anaerobic digestion of organic matter inside the chamber produces gases, mainly methane, which has a high energy (fuel) potential. The gas pressure increase pushes effluent to the outlet. Similarly, the weight of the liquid in the output access area pushes back the content of the chamber, maintaining constant gas pressure. Biodigesters require a higher temperature than septic systems. To start digestion, the user ought to add cow dung or septic sludge. Organic waste is used as a substrate and must be mixed with water before input.
      2. These systems contain significant gas build-up and should not be made of plastic. Before the first box, a check valve is installed, where the manure with water may be added periodically. The box lids are black and must be exposed to the sun. The boxes are buried and sealed to ensure the maintenance of a high temperature inside. Both first boxes will have a vent installed in the lid for the exhaust of digestion gases. The manure mixture enters the first box where it ferments together with the black water. The effluent is sent to ditch infiltration or a similar system.
   D. Output:
      1. Effluent to subsurface fertigation.
      2. Biogas.
      3. Sludge.
   E. Maintenance and monitoring:
      1. The valves and conduits should be regularly cleaned to avoid corrosion and leakage.
      2. Approximately once a month add X number of liters of water with X number of liters of fresh manure from cattle, goats, or sheep, through the retaining valve placed before the first box. The system should be monitored regularly.
4. Risks
   A. The effluent from all anaerobic systems should never be used for spraying or surface fertigation (fertilized irrigation), because of the high potential for contamination by pathogens.
   B. These systems must be sized correctly for volume and flow.
   C. The tanks can break, causing contamination of

the area.
D. Blockages.

7.4 Combined black and gray water treatment

Blackwater ecological treatment generally follows the following steps (i.e., the water is forced through a series of digesters, filters, and absorbers, and is cleaned along the way):

1. Anaerobic septic tank - allows for solids to settle out in a septic tank (which may also act as a biogas producer).
2. 2nd anaerobic tank - to digest some of the sludge material.
3. 1st oxygen rich plant filled tank - where plants and aquatic animals live and oxygen is pumped in to facilitate aerobic digestion. Water is pumped in at the bottom and exits at the top.
4. 2nd oxygen rich plant filled tank - where plants and aquatic animals live and oxygen is pumped in to facilitate aerobic digestion. Water is pumped in at the bottom and exits at the top.
5. 3rd oxygen rich plant filled tank.

7.4.1 Evapotranspiration tank systems

A.k.a., Absorption system.

An evapotranspiration (ET) tank is another technique that can be used with most black water (except, industrial/ production chemical usage). Evapotranspiration/ absorption systems are designed to disperse effluent exclusively by evaporation, transpiration and absorption. Evaporation is the movement of water from the soil to the atmosphere through evaporation and plant inspiration, and is directly impacted by precipitation, climatic factors, and plants. Transpiration involves the removal of water by vegetation or how much water plants can soak using their roots. Absorption relies upon the percolation of water through the soil. Anaerobic digestion occurs inside the tank. As this type of system has only primary treated the effluent, and is regarded as a higher risk to public health and safety. Most local governing authorities prefer to have wastewater treatment systems installed, as they secondary treat the effluent. In installations after a septic tank, the septic tank is typically located upslope of the transpiration "bed", so effluent will disperse through the transpiration trenches by gravity. In some installations a submersible pump is required to be installed in the effluent chamber of the septic tank to pump effluent to the transpiration field. Products such as splitter boxes may need to be installed to distribute effluent evenly, if a number of trenches have been installed. The system will release biogas and must be vented. These systems function most effectively in areas where annual evapotranspiration rates exceed the loading rate of the system from rainfall and wastewater (i.e., arid climates).

The loading rate for an ETA system is generally more than that of an ET system in the same climate. And, an ETA system can be used in a wider range of climate conditions. As with any soil absorption system, the general rule stands that wastewater must travel through two to four feet of unsaturated soil for adequate treatment before reaching groundwater.

The evapotranspiration/absorption trenches consist of an excavated tank area. The pipe or receiving chamber area is then placed in the ditch. The pipe or chamber is filled with one or more layers of different substrates. The receiving pip/chamber is then backfilled with the gravel. The whole system is then covered with soil (natural ground) and planted with fast growing, high water consumption plants. High water usage plants are then planted on top of the soil. The effluent enters the hollow center of the system by a pipe that is also vented. There may be other vents in the system. The blackwater enters the system through a reception chamber/pipe of the tank, and then permeates outward and upwards through layers of bricks and rocks. In the absorption version, it also drains into the soil.

The construction and operation of the system is as follows:

1. Versions:
   A. The lined evapotranspiration (ET) system disposes of wastewater without permitting effluent to move into the soil.
   B. The unlined evapotranspiration/absorption (ETA) system is similar, but is constructed without a waterproof/impermeable liner to permit a very slow rate of seepage (absorption) into the ground.
   C. An ET tank system connected to a second aerobic tan system. It consists of two waterproof tanks in series. The first tank is a normal evpotranspiration (ET) tank, and the next is a tank with no inner conduit. This sytem is not intended to evapotranspire all of the effluent. Some of the effluent rises to the top of the first tank and flows into the second. Hence, this evapotranspiration system is designed for light gray water, but in emergencies could hold black water. This system does not work well with textiles, fibers, and hair. Fat is likely to clog this system and should be separated beforehand. This system may also need the chamber cleaned out periodically.
2. Inputs:
   A. Black water or brown water, with the exception of production chemicals). This system should only be used for small amounts of grey water and should not be used for other types of water.

3. Process:
   A. The black water is digested by anaerobic processes in the semi-permeable tube and in the surrounding media. Moisture is wicked up to plant roots and to the soil surface. The water is evaporated by the soil and transpired by the plants. In the drainage version, some of the water drains slowly into the soil.
4. Output:
   A. Gas and biomass.
5. Maintenance and monitoring: This system does not require operation and maintenance, but it is important to monitor the inspection tube.

7.4.1.1 Sizing the evapotranspiration drainfield

The amount of surface area needed for the evapotranspiration (ET) drainfield can be determined using this formula (*Evapotranspiration Systems*, 2000):

- A = Q/ET - Pr
- Where,
  - A = total bed surface in square feet (or square meters)
  - Q = annual flow in cubic feet per year (cubic meters/year)
  - ET = annual potential evapotranspiration rate in feet per year (meters/year)
  - Pr = annual precipitation rate in feet per year (meters/year)

If using an ETA system, the formula adds a factor for the annual percolation rate (P) of the soil in feet per year (*Evapotranspiration Systems*, 2000):

- A = Q/ET - Pr + P
  - Where,
    - P = percolation rate of the soil in feet or meters per year

7.5 The final ecological grey water re-cycling processes (final step in recycling waste water)

Treated effluent output, grey water and yellow water can be infiltrated and sent to final ecological re-processing:

1. Infiltration (only, or with plants).
2. Clean the water with biologically active soil and plants.
3. Moderate what is put down the drain.
4. Use woody perennials in the system.
5. Avoid root infiltration by having air gaps.
6. Keep it all underground.
7. Do not do this in environments with a shallow water table. Good soil drainage is required to keep the grey water below the surface.

The disposal of nutrients in the soil can be a good source of water and nutrients for crops. It can be made by ditches of infiltration or underground irrigation pipes. When the infiltration is done subsurface, the water percolates horizontally, by capillarity, and may be available for trees and crops. The nutrients are made available to plants by nutrification and mineralization processes that take place in treatment systems and the soil itself. In addition to availability for plants, soil disposal promotes aquifer recharge. If the water table is not very shallow, the clearance made by the layers of soil and subsoil is sufficient to guarantee the quality of groundwater, in a similar way to what happens in nature.

There are many techniques to hand the final ecological re-processing phase:

1. **Sinkhole** - is a well that allows the penetration of effluent from the septic system into the soil. The diameter and depth of the sinks depend on the amount and type of soil. The smaller the depth of the sink, the greater will be the storage of water in the soil, benefiting plants around. Sinkhole infiltration works best in places where the water table is low. This method uses infiltration to drain, sink, and store water in the aquifers and/or deep soil.
   A. Inputs:
      1. Effluent from a septic tank or other form of treatment.
   B. Process:
      1. The effluent is directed to the interior of the sinkhole and gradually seeps through the soil, depending on the percolation capacity.
   C. Output:
      1. Water that recharges aquifers.
   D. Maintenance and monitoring: This system does not require operation and maintenance, but it is important to observe if the effluents to be infiltrated need the step of separation of solids and fats to avoid clogging and/or soil sealing over time.
2. **Infiltration well** - is similar to the sinkhole, but is filled with stones or other filter/void-filling material. Ideally for smaller flows of effluents and soil application at lower depths, with greater use for storing water in the soil, benefiting surrounding plants. This method uses infiltration to drain, sink, and store water in the aquifers and/or deep soil.
   A. Inputs:
      1. Treated effluent water, grey water, and yellow water.
   B. Process:
      1. The effluent penetrates inside the well,

is distributed through the stones and penetrates the soil through the holes in the wall and bottom. If the volume of effluent is small, there may be conditions of aerobic decomposition of organic matter, being indicated for gray water treatment (with the exception of water from the kitchen sink). If the volume is large, this system should only be used for treated effluent.

C. Output:
   1. Water for ground storage and aquifer recharges.

D. Maintenance and monitoring: This system does not require operation and maintenance, but it is important to observe if the effluents to be infiltrated need the step of separation of solids and fats to avoid clogging and/or soil sealing over time.

3. **Infiltration ditch (infiltration trench, effluent disposal field, absorption field, filtration ditch, ditch infiltration, infiltration galleries, etc.)** - consists of a perforated conduit running through a layer with crushed stones and aligned inside ditches covered with soil of the installation location itself. This system is similar to an infiltration well, but is in the linear shape of a channel. The water runs through the infiltration ditch and drains into the surrounding soil. Infiltration trenches are underground (and directly connected to a top layer). They are linear excavations in length, and rectangular or trapezoidal in shape. They have either level or gently sloping bottom grade. Generally, the sidewalls and top of the ditch are geotextile filter fabric. The inside of the trench itself is filled with clean, crushed angular stone or other void-forming structures. These water transportation structures are well suited to sites where available space for infiltration is limited to areas where drainage is needed in a small area of land, and near transportation roadways. This technique is used for both regular rainwater drainage as well as post-treatment and soil disposal of effluents from treatment systems. The ditch could alternatively be lined with a permeable membrane, perforated tubes, bamboo poles or hollow bricks aligned in the direction of the holes. The purpose of these structures is to flow and distribute water inside the trench, to fill the void, and to optimize drainage (for the type of soil and groundwater level). The ditch may be filled with gravel up to half and covered with soil. It could also be covered with gravel. The frenchwater drain is a similar construction, which allows water to flow within it and is entirely permeable. However, a frenchwater drain is built under the soil with soil on-top (i.e., no direct link/air movement potential between the drain and the surface, except for possibly an access/cleanout box). Between the soil and the gravel is a geotextile blanket can be placed, used for drainage of gardens. At least two trenches must be constructed for soil infiltration in parallel, and its length depends on soil infiltration capacity. If connected to a septic system, then this where natural soil processes kill off more pathogens and break down the harmful toxins. It is important that this is a slow, safe process as too much effluent can overwhelm the soil and flow into subsoil pathways and drainage channels.

A. Inputs:
   1. Treated effluent, grey water, and yellow water.

B. Process:
   1. The conduit distributes the effluent along the ditch, allowing its subsurface infiltration. The efficiency of the process in removing nutrients and pathogens from the water to recharge aquifer depends on the characteristics of the soil.

C. Output:
   1. Water to recharge aquifers and storage of water in the soil. Plant biomass if positioned near or around the trench.

D. Maintenance and monitoring: Does not require operation and maintenance, but it is important to note whether the effluents it be infiltrated require the step of separation of solids and fats for preventing clogging and/or waterproofing of the soil along the trench over time.

E. The design of soakage treatment area should be:
   1. Large enough to cope with the amount of wastewater produced.
   2. As dry as possible, because pathogens survive better in waterlogged soil.
   3. Shallow, which allows plants to absorb nitrates and organisms in the soil and the heat/UV of the sun to act on pathogens to remove them.
   4. Away from waterways, flood-prone areas and areas of stormwater runoff.
   5. Surface water should be diverted around any effluent disposal field.

4. **Mulch filtration ditch circularly positioned around a central plant (drain leads to ditch around a central plant in soil)** - Area for disposing of grey water or treated effluents for localized fertigation of trees. This system uses evapotranspiration and infiltration, along with other ecological processes, to clean water and refill aquifers. This is a soil and plants-based hybrid system. A smooth cavity around the plant (typically

a high-water demand fruit tree) is filled with mulch (straw and other types of organic dry matter), where liquid effluent is infiltrated. At the outlet of the pipe into the infiltration cavity, a small chamber can be placed with stones to avoid clogging. The soil cavity facilitates the infiltration of the effluent and the mulch layer maintains ideal conditions for development of aerobic bacteria that complete the digestion of organic matter and make the nutrients available in the effluent to the plants. The design typically has a maximum depth of 50cm, according to the structure of the roots. The ideal is to assemble the system at the moment the seedling is planted, avoiding damage to the roots by digging the cavity at the same time. The tree selected is typically a fruit species with a high demand for water.

A. Inputs:
   1. Treated effluent, grey water, and yellow water. Note that the system requires a fat trap if it receives effluent from the kitchen sink.
B. Process:
   1. Effluent from small flows will flow into the ditch/cavity and infiltrate. Larger effluent flows can be distributed among several systems like this.
C. Output:
   1. Water to recharge aquifers and storage of water in the soil, biomass of plants and transpiration.
D. Maintenance and monitoring: Cultivation of the plant (tree), harvesting of fruits, superficial replacement of the mulch, which decomposes and is naturally incorporated into the soil.

5. **Mulch filtration ditch/basin with plants (trees) positioned circularly around it (i.e., drain leads to center of basin surrounded by plants; a.k.a., banana circle)** - Area for disposing of grey water or treated effluents for localized fertigation of trees. This system uses evapotranspiration and infiltration, along with other ecological processes, to clean water and refill aquifers. This is a soil and plants-based hybrid system. A basin with plants (typically a high-water demand fruit tree) around the ditch. The basin filled with mulch (straw and other types of organic dry matter), where liquid effluent is infiltrated. The effluent enters the system in the center of the circle. If the system uses straw and wood, then that will collect excess fats. The water and nutrients are absorbed by the roots of the plants around the circle. The pipe outlet is positioned in the center of the basin. The center basin is filled-in with the following layers from bottom to top: woods, branches, leaves and straws. And probably, adding a final layer of leaves for a better aesthetic affect. Note that this system is sometimes called a permacultural banana circle, because banana plants are the most common planted used (however, any plant with a fiberous root system and not single tap root will probably work).
   A. Inputs:
      1. Treated effluent, grey water, and yellow water. Note that the system requires a fat trap if it receives effluent from the kitchen sink. This system is not recommended for the treatment of black water. This can be used as a final destination for treated effluent, thus replacing the sink and infiltration ditch
   B. Process:
      1. Effluent from small flows will flow into the ditch/cavity and infiltrate. Larger effluent flows can be distributed among several systems like this; it also depends on soil type.
   C. Output:
      1. Water to recharge aquifers and storage of water in the soil, biomass of plants and transpiration.
   D. Maintenance and monitoring: Cultivation of the plant (tree), harvesting of fruits, pruning the plants, addition of organic material (replacement of the mulch), which decomposes and is naturally incorporated into the soil, and humus (buildup of organic matter over time).
6. **Branch drain grey water system (i.e., drain leads to bucket in basin surrounded by plants)** - a drain goes into a central porous bucket with the bottom cut out and holes drilled into the side, and covered by a lid whose bottom rests at surface level. The bucket is surrounded by wood chips or other coarse mulch. There is no contact between the pipe and the soil. One of the main problems with these systems when not installed correctly is having them clogged with roots or mulch. Around the basin of mulch are planted perennial trees, whose roots find their way into the wood chip sponge. This system uses evapotranspiration and infiltration, along with other ecological processes, to clean water and refill aquifers. This is a soil and plants-based hybrid system. The wood chips buffer the hot water.
   A. Inputs:
      1. Treated effluent, grey water, and yellow water.
   B. Process:
      1. Effluent flows out of the pipe and falls to the bottom. The water then soaks into the wood chips and infiltrate into the soil. Eventually the wood chips break down into soil.

C. Output:
   1. Water to recharge aquifers and storage of water in the soil, biomass of plants and transpiration.

D. Maintenance and monitoring: The tile/cover at the surface top of the bucket can be removed to check on the system. Cultivation of the plant (tree), harvesting of fruits, pruning the plants, addition of organic material (replacement of the mulch), which decomposes and is naturally incorporated into the soil, and humus (buildup of organic matter over time).

7. **Wetland water treatment (wetlands construction (root zone baths)** - a type of treatment system designed to reproduce natural processes (as in, swamps and floodplains), used in a post-treatment step. For effluent cleaning, that is the removal of pathogens and nutrients. Constructed from a waterproof tank filled with a bed of filter material, also called substrate, which serves as a support for aquatic plants. The most used materials for the substrate are crushed stone (gravel) or sand. Various alternative materials are possible, including shards of tile, coconut shell, oyster shells, and bamboo. The optimal wetland treatment water system creates the maximum amount of contact between the dirty water and the roots without any blockages. To construct a typical wetland, water flows into a gravel filled (lengthy basin that is planted with wetland plant species. The basin is lined with either plastic, cement, or some other material to prevent the water from seeping into the ground. The water flows under the gravel so that dirty water isn't highly exposed to the air. This system uses a wetland ecosystem (without infiltration), to clean water. At the end of the system, after the big plant and organism filter, much cleaner water comes out. This is an aquatic plants-based system.
   A. Input:
      1. Effluent of septic system, preferably grey water from digestion of organic matter.
   B. Process: The bacteria that grow in the filter medium and plant roots promote digestion of organic matter, nutrient removal, pathogen removal and retention of solids. Three levels of root zone come into contact with the effluent.
      1. Vertical flow root zone - effluent is distributed along the bed surface (composed of a filter medium), infiltrating vertically through the zone from pant roots and draining at the bottom.
      2. Surface flow root zone - the surface of the water is exposed to the atmosphere.
      3. Flow roots zone subsurface - the bed remains flooded until one level below the surface.
   C. Output: Biomass of plants and cleaner effluent, which can be used on soil.

7.6 City sewage treatment

The sewage from cities is treated in what are known as sewage treatment plants. These plants are typically placed away from residential and commercial zones because they frequently smell like raw sewage.

The process of treating and recycling water at a city sewage treatment facility is often as follows:

1. Sewage treatment plants are generally placed downhill of the pipes that drain to them.
2. The raw sewage undergoes preliminary treatment in the headworks, which removes large solids, such as plastic and rags, using a series of mechanical screens and bars. It is possible for large items that got caught in the system or incorrectly disposed of can clog the system, necessitating their separate removal. This sub-system can be optimized by only putting down the drain (and/or allowing to pass) appropriately sized and compositioned objects.
3. The sewage then goes into a settling tank to separate sludge from water (similar to a septic system, but built outdoors and may be exposed to air). However, it is often preferable for them to be built below grade and covered, to reduce odors.
4. Any wastewater that does not sink to the bottom is skimmed off the surface of the water.
5. The sewage is passed through one or more aerobic digestion systems, where the bacteria rich wastewater is oxygenated to breakdown organic solids remaining from the earlier treatment. These digesters may or may not be open to the air.
6. The effluent is passed through one or more clarifying tanks for final settling and collection. Since the effluent is no longer as pungent, the outdoor clarifying tanks are open to the air.
7. The clarified water is then chemically treated with a variety of potential chemicals before being redistributed to the population. These treatment chemicals include, but not limited to:
   A. Continued disinfection:
      1. Ozone.
      2. Chorine.
      3. Chloramine.
   B. Human purposes:
      1. Minerals.
      2. Flouride.
8. The solid sludge (biosolids) are removed from sewage during the anaerobic (septic) treatment as

well as the aerobic treatment are put in digesters (often egg shaped) to produce biogas. Throughout this process the facility collects biogas.

9. Once digested sufficiently, the biosolids are "a pathogen-free US Class A organic product, suitable for many landscaping and agricultural applications) as a fertilizer." Digested biosolid material may be further treated and/or heated to finish the process. This material may still contain pollutants.

In the past, and in some poorer places in the world, the people and municipalities simply dump and pumping untreated sludge and sewage into water bodies. This is considered a serious ecological and human hazard.

NOTE: *Rainwater sewage is simply directed to an appropriate water body.*

8 Cleaning-water units and processes

A.k.a., Cleaning with water units and processes.

Regular cleaning of material surfaces reduces the build-up of environmental materials and decomposition factors, while also reducing the amount of organic (and inorganic) matter that contributes to the proliferation of bacteria and viruses, and may inhibit the intended functioning of the surface. The purpose of cleaning is to remove the build-up of materials and to prevent future accumulation. Cleaning is essential for food production and preservation, as well as for the care of textiles. Cleaning must be considered in the context of an ecology, in particular, a bacterial ecology:

1. **Physical / mechanical pressure cleaning** - a process that utilizes mechanical energy (e.g., washing machine, pressure washing, scrubbing).
2. **Ultrasonic cleaning** - a process that utilizes sound energy to create cavitation of microscopic bubbles on the surface of an object.
3. **Chemical cleaning** - a process that utilizes a chemical agent.
   A. Water (at various parametric chemistries).
   B. Soaps and detergents.
   C. Ozone in water.
   D. Alcohol (solvent) with water.
   E. Hydrogen peroxide water (3%).
   F. Etc.

Some methods of cleaning instruments and other objects with water include, but are not limited to the following chemical+mechanical processes:

1. **Dish/instrument washing (and sanitizing) machines (chemical bath, possibly with agitator):** These machines rely on the following parameters to clean an object:
   A. Pressure (and volume) of liquid.
   B. Time.
   C. Temperature.
   D. Surface tension modification (often, via a washing agent or soap).
   E. Chemical additions (e.g., solvents).
2. A **sponge (abrasion)** is a tool or cleaning aid consisting of porous material. Sponges are usually used for cleaning impervious surfaces. They are especially good at absorbing water and water-based solutions. Natural sponges are generally known as a "loofah". A natural loofah is a plant seed pod in the cucumber or gourd family that grows on a vine. The pod is rough textured when dry, and softens when combined with water.
3. **Fabric washing machine (chemical bath,**

possibly with agitation) is a machine that uses water and other chemicals to clean fabrics.
4. **Pressure washing (chemical and mechanical)** machines is a machine that uses liquid and/or air (or other gas) pressure to clean a surface.

The performance of a "cleaner" can be measured via the following indicators:

1. If a product leaves any residue from the detergent solution, then it is not clean.
2. If a product adds to the weight of the material, then it is not clean.
3. If the cleaning damages the surface unnecessarily, then it is a poor quality cleaner.

8.1 Mechanical [pressure] washing

Pressure washing uses a high-pressure mechanical sprayer used to remove material from surfaces and objects such as buildings, vehicles, and concrete with water [under pressure]. They are used primarily as exterior cleaning tools. The volume of a pressure washer is expressed in litres per minute, and may be variable or static. The basic pressure washer consists of a motor (either electric, internal combustion, pneumatic or hydraulic) that drives a high-pressure water pump, a high-pressure hose and a trigger gun-style switch. Just as a garden hose nozzle is used to increase the velocity of water, a pressure washer creates high pressure and velocity.

Some washers, with an appropriate nozzle, allow detergent to be introduced into the water stream, assisting in the cleaning process. Different pressure washers can use water at differing temperatures. And, there are different types of nozzles for different applications.

Washers are dangerous tools and should be operated with due regard to safety instructions. The water pressure near the nozzle is powerful enough to strip flesh from bone. Particles in the water supply are ejected from the nozzle at great velocities. The cleaning process can propel objects dislodged from the surface being cleaned, also at great velocities. Pressure washers have a tendency to break up tarmac if aimed directly at it, due to high-pressure water entering cracks and voids in the surface. Washers can damage surfaces: water can be forced deep into bare wood and masonry, leading to an extended drying period. Such surfaces can appear dry after a short period, but still contain significant amounts of moisture that can hinder painting or sealing efforts.

8.2 Cleaning with water 'washing agents'

The two primary types of washing agents are soaps and detergents. The distinction between them is relatively small. One hundred years ago there was no such thing as a "detergent". Today, a "detergent" is anything that grabs onto dirt, soil, grease, oil, odor, bacteria, etc. and holds it well enough to loosen its grip on clothing, skin, hair, wall paint, etc. and pull it into the wash water. If the detergent hooks-up too well it may join the dirt on the fabric or surface and become part of the problem (soap and detergent scum). The cleaning agent must remain well attached to the water so that as the water rinses away, the detergent goes with it still holding fast to the dirts and soils it has released from the material being cleaned. Effectively, the cleaning agent allows insoluble particles to become soluble in water, so they can be washed away. This is how cleaning works whether it is called "soap" or "detergent". The category difference relates to how the cleaner (i.e., cleaning/washing agent) is created (i.e., materialized). A detergent or soap molecule is different on one end from the other. One end is attracted to "dirt" and the other is attracted to water.

> **IMPORTANT:** *Calculate and use the right detergents and amounts for the different fabrics, given safe detergent cycling products.*

Every washing agent contains chemicals to separate added material (a.k.a., "soil") from a surface (e.g., fabric) and carry it away with the water. These are called **surfactants (Read: surface active agents/ substances)** and they do whatever "cleaning" occurs. A properly designed and selected washing agent (i.e., surfactant) should remove matter efficiently from a surface and wash away completely without residue. In order to achieve this, a synergistic blend of two or three compatible surfactants is generally required.

Whereas soap is a metal salts of long chain higher fatty acids, detergents are sodium salts of long chain hydrocarbons like alkyl sulphates or alkyl benzene sulphonates. Soaps are prepared from vegetable oils and animal fats. Detergents are prepared from hydrocarbons of petroleum or coal and are "soapless". Soaps cannot be used effectively in hard water as they produce "soap scum" (i.e., insoluble precipitates of Ca2+, Mg2+, Fe2+ etc.). Detergents are generally not made insoluble by mineralized (so-called hard) water. The polar sulfonate (of detergents) is less likely than the polar carboxyl (of soap) to bind to calcium and other ions found in hard water. Some detergents also have secondary usages as acid solutions and foaming agents. Soap cannot be used as any form of acid solution, but it is sometimes used as a [component of a] lubricant (e.g., textile spinning). Whereas soaps are biodegradable, not all detergents are biodegradable.

- An example of a soap is sodium palmitate: $CH_3(CH_2)_{14}\text{-}COO^- \ Na^+$
- An example of a detergent is sodium lauryl sulfate: $CH_3(CH_2)_{12}\text{-}OS(O)_2\text{-}O^- \ Na^+$

Water, although a good general solvent, is also a substance with a very high surface tension. Because of this, water molecules generally prefer to stay together, rather than to migrate to other surfaces. **Surfactants** work by reducing the surface tension of water, allowing the water molecules to better wet the surface and thus increase water's ability to dissolve dirty, oily stains. Soap technology is essential for the removal of oil molecules from a surface. Oil molecules are non-polar, which means that they are not charged, and therefore, are not attracted to polar substances such as water (lipophilic). Because of this, oil tends to stick with its own molecules or other non-polar substances. Water is a polar substance which is made up of one positive and one negative charge. With this, water dissolves salt easily because salt is made up of charged ions in which the positive charge will be attracted to the negative ions in water (hydrophilic). When an appropriate surfactant is applied to oil, the lipophilic parts of surfactant will attach itself to the non-polar molecules of the oil. When water is applied onto this surface with a sponge, the hydrophilic component will be attracted to the water molecules and is lifted from the surface, together with the oil. Also, oil and grease will stick onto plates and cutlery during cleaning, and no amount of water can completely remove it without significant temperature and pressure, unless a surfactant is present.

> **NOTE:** *The presence of surfactants affects the natural micro-organism ecology.*

A surfactant (once dissociated in water) consists of a non-polar hydrocarbon tail and a polar head. The non-polar hydrocarbon tail interacts with non-polar substances through dispersion forces, whilst the polar head interacts with polar substances (normally water) which forms dipole-dipole interactions and hydrogen bonds with water. The presence of soap, for example, in a mixture of oil/grease and water will create an emulsion upon agitation. The hydrocarbon tails of soap dissolves in the oil and promotes droplet formation. These droplets repel each other, as they have the same net negative charge. These individual droplets can be dissolved in water as they form ion-dipole interactions.

An **emulsion** is a type of dispersion in which two normally immiscible substances are stabilised by another substance, called an emulsifier. For example, olive oil and water will not dissolve in one another, as their intermolecular forces differ (like dissolves like). While we can agitate to form a suspension, it is temporary and the oil and water will eventually separate into distinct layers.

8.2.1 Soap

Soaps are cleaning agents that are usually made by chemically reacting alkali (e.g., sodium hydroxide) with naturally occurring fat or fatty acids in order to facilitate the removal of organic and in-organic matter from the surface of a material. The metal is often an alkali metal such sodium or potassium, or an alkaline earth metal, such as calcium or magnesium. The fatty acid is often of plant or animal origin. Essentially, soap is a result of combining fat (i.e., oil) with an alkaline solution, and the productive chemical reaction is called **saponification**. The reaction produces sodium salts of these fatty acids, which improve the cleaning process by making water better able to lift away fatty material from skin, hair, clothes, and many other surfaces.

Historically, soap was made by boiling animal fat and adding lye to supply charged ends for the oil molecules. Time and temperature cause various combinations to occur and each will interact differently with the soils and especially with the calcium and magnesium in the wash water.

1. Soap is most effective when mixed with mechanical pressure.
2. Different oils and alkali solutions produce soaps with different properties. Especially coconut oil and palm oil produce excellent lathering properties.
3. Temperature is a significant variable when using soap.
4. Essential oils are sometimes added to soaps for their aromatic and anti-pathogenic properties.

8.2.2 Natural cleaners and soap

Natural ecologies produce a range of "soft" soap materials that are useful for cleaning. Although rare, soap is indeed found in nature. One family of historical soaps was made by infusing, simmering or mashing 'saponin' rich plants in water. If you have seen frothy puddles on the road near chestnut trees you have got the idea. Plants produce saponins as part of their immune system to deter insect attack and to act as natural anti-microbials, protecting their life bearing seeds. Hunter gatherers still exploit the soap-bearing plants for their medicinal properties and for cleaning. Grated or pounded horse chestnuts (aesculus hippocastanum), soaked and boiled bracken root (pteridium aquilinum), fern root (dryopteris filix-mas), snowberries (symphoricarpos albus), and soapwort (saponaria officinalis) will yield a soft water-based soap. There are certain leaves that when diluted in hot water, form a weak cleaning solution. Two of the most well-known leaves for this purpose are palm and bay leaves.

In an emergency when soap is not available, then there are many natural alternatives including: clean ash; vinegar, salt, mud, and sand/soil. Mud is a lesser known cleaner for hair (i.e., "shampoo") commonly used in the Mashreq and Maghreb regions.

Both baking soda and salt are excellent scouring powders. Baking soda is an excellent stain and odor remover. The solution can be used as a facial scrub. It can also be used as a toothpaste and tooth whitener. Clay can also be added to toothpaste to fa-ciliate whiter teeth due to its abrasiveness.

Vinegar is a natural all-purpose acidic cleaner with anti-microbial properties. It is sometimes added to a surfactant solution to increase its effectiveness. Vinegar can be used to "clean" most standard surfaces including ceramic, glass, and fabrics. Vinegar cannot be used on marble or similar surfaces because its acid content will damage (i.e., "eat away") the surface, and quickly lose its shine.

It is possible to wash clothes (fabrics) in a washing machine with a variety of natural chemicals, including but not limited to:

> **NOTE:** *Of course, if clothes are particularly dirty, then a stronger chemical washing agent will be required.*

1. Just vinegar: It is possible to simply wash many types of clothes in a washing machine with just vinegar and have them come out clean.
2. Washing soda and borax: 1 tbs of washing soda and 1 tbs of borax powder.
3. Soap nuts: The soap nut tree Sapindus Mukorossi (a.k.a., Indian Soapberry) is a very large tree that produces prodigious amounts of a saponifying nut that you can use as a greywater safe laundry detergent, dish and hand soap. Soap nuts are berries that grow on a tree and naturally contain soap. Sapindus Mukorossi requires a fertile soil and a frost free climate. It's a tall tree that can take as long as ten years to begin fruiting. Just 5 berries can do multiple loads of laundry in a conventional washing machine. The natural soap found in these berries is called saponin. Saponin is a natural cleaner that works as a surfactant, breaking the surface tension of the water to penetrate the fibers of your clothing, lifting stains from the fabric, and leaving dirt suspended in the water that is rinsed away.

8.2.3 Hydrophilic-lipophilic balance (HLB)

A system was developed to assist in making systemic decisions about the amount and types of surfactants needed in stable products. **Surfactants** are compounds that lower the surface tension (or interfacial tension) between two liquids or between a liquid and a solid. Surfactants may act as detergents, wetting agents, emulsifiers, foaming agents, and dispersants. The hydrophilic-lipophilic balance of a surfactant is a measure of the degree to which it is hydrophilic or lipophilic, determined by calculating values for the different regions of the molecule. The system is called the HLB system and has an arbitrary scale of 1-18. HLB numbers are experiment ally determined for the different emulsifiers. If an emulsifier has a low HLB number, there are a low number of hydrophilic groups on the molecule and it will have more of a lipophilic character. For instance, substances with low HLB numbers are generally oil soluble. As a result of their oil soluble character, they will cause the oil phase to predominate and form a water-in-oil emulsion. The higher HLB numbers would indicate that the emulsion has a large number of hydrophilic groups on the molecule and therefore should be more hydrophilic in character. Substances with high HLB numbers are water-soluble. And because of their water soluble character, they will cause the water phase to predominate and form an oil-in-water emulsion.

8.2.4 Detergent washing agent residue

Most commercial cleaners are filled with additional chemicals. Industry is not overly concerned with sustainable and efficient cleaning, and so, they create a chemical soup of additives. There are thousands of synthetic fragrances and over 200 brighteners which might be called dyes, colorants, color enhancers, color safe bleach, fluorescent whitening agents (FWA), etc. Then, manufactures add oils, silicones, and polymers to attach the fragrances and brighteners to the washing agents. Lubricants are added to make the fabrics less stiff, other lubricants for the washing machine pump, polyvinylpyrrolidone to seal the surfaces and ends of fibers, antiredeposition agents, perhaps sanitizers (anti-microbial agents), enzymes and oxidizers, also softeners, and of coarse inert fillers so you know by the size of the expensive containers that you got your moneys worth.

> **NOTE:** *In commercial products, the highest levels of fragrance are often found in "Baby" detergents. These fragrances can mask natural body odor/pheromones.*

Fabric softeners coat the surface of a fabric with chemical compounds that are electrically charged, causing threads to "stand up" from the surface, and thereby, causing the fabric to feel softer.

Oxidizers (oxidizing agents) and enzymes react with the smooth surface of fibers causing tiny pits and fissures that hold particles of residue. As temperature and humidity change, these imperfections swell and shrink. The eroded surface scatters light causing colours to look bleached and faded and the fibers weaken, loose memory, and eventually break. Elastomers fail significantly more quickly under these conditions than other fibers.

Optical brighteners are added to make the clothes appear cleaner. It would seem that if you can't clean clothes with less than six chemicals, maybe you're not focused on cleaning. Most of the other ingredients in commercial products are there to help the surfactants, or they are present to make you believe your clothes are clean, and hence, must remain in your clothes to be effective (e.g., optical brighteners).

Gutting (2020) clarifies the effects of some modern detergents on clothing:

> *Tests done at the Clemson University School of Textiles and Polymer Science (Nicholson, 1995) showed that washing in regular grocery store detergent actually added a measurable amount of weight (contamination) to the clothes. Washing added 2% of the weight of the cloth in just 10 washings. The residue was equal to the*

full amount of detergent recommended to wash clothes. Let me be specific about this. When you pour in the detergent before the wash cycle, the scoop of powder or cup of liquid, you use is equal to the amount of chemical you will have in your clothes after 10 washes. It doesn't increase much beyond 10 washes because you reach a point where you are washing out as much as you are washing in.

Detergents for colors and blacks have higher levels of polymer, which attaches to the clothing, to hide the scattering of light (i.e., "fading") caused by fiber erosion.

The latest news in home laundry detergents is a Proprietary Protective Fiber Complex. This goes beyond polymers to a new silicone complex that not only provides additional lubrication, but also forms little cells of oiliness to keep the silicone complex and other care ingredients from washing away. This technology is especially important for high efficiency (HE) washing machines. The new machines not only save water and power, but rinse clothes more completely. Better rinsing is good for you but makes it difficult for the detergent makers to leave enough residue to assure you that your clothes are clean. Detergent makers had initially been forced to add more of the "care" chemicals, but this new technology allows them to overcome the great rinsing performance of your new HE machine and attach exactly the right amount of residue to your clothes.

Of course, residue is not without consequence. It impacts the functioning of a material. It can degrade wicking, breathability, rapid drying, and water repellency in just a few washings. Detergent residue may not only slow drying, but will rehydrate itself when dry by drawing moisture from the air or from its user. Extra moisture reduces the efficiency of insulation. Insulation is also less able to loft up when coated with sticky residue, this further decreases effectiveness. Fabrics feel stiffer when coated with sticky chemicals because fibers cannot slip against each to allow a soft hand. Detergent manufacturers try to overcome some of this friction with silicone but deliberately leave some stiffness to ensure an opportunity to sell fabric softener. It is only a small exaggeration to say that washing clothes in regular detergents destroys them as fast as not washing them at all.

What are the effects of detergent residue on humans? An increasing slice of the population is experiencing episodes of eczema, psoriasis, and other reactive skin irritations loosely referred to as contact dermatitis. Humans will inevitably get the residue on their hands and likely end up consuming some of it. The human organ known as the skin may absorb some of it.

8.2.5 Overuse of soap

Cleanliness has come to mean an effort to remove germs and other hazardous materials. Today we now know that bacterial populations play an important role in the sustainment of a healthy ecological system, and in humans, a healthy immune system. Although cleanliness as the removal of dead cells, decomposition matter, contaminants, and excessive build-up of microorganisms and viruses has an important role in healthy functioning, excessive cleaning is often unnecessary and can damage surfaces.

It is the body oils forming a thin film on the surface of the skin that give human skin its smoothness. When the oils are washed off the body (i.e., stripped off of the skin) it tends to reduce the smoothness and "glow" of the skin. Now when you lather your body with soap during your bath, the lipophilic part attaches itself to your body oils and the hydrophilic part attaches itself to water. When you wash off the soap with water, your body oils are wrenched off from the skin and are washed of with the water. Your skin is deprived of its natural moisture but it gives you a feeling that you are cleaned/scrubbed. This feeling basically comes from the skin reporting the lack of an essential ingredient which we mistakenly feel to be fresh. You feel that you are cleaned off of all the "dirt" and that you are fresh. What really happened is that your body moisture is washed off and you need to replenish the body moisture. The soap industry realized what their soaps are doing to people and started adding moisturiser to the soap itself so that what is washed off by the soap part is replenished by the moisturiser. Excessive washing to remove oil from the skin also prevents vitamin D both from being formed on the skin and absorbed via the oils through the skin [via exposure to sunlight]. It is also relevant to note that soap is not essential for the removal of many pathogens from the hands.

8.3 Cleaning with disinfectants and sterilizers (and fine cleaning)

There are water-inclusive chemical solutions that will clean by killing life:

1. To **disinfect** means to eliminate most harmful microorganisms (not including their spores) from surfaces or objects, and to inactivate viruses. Drinking water must be disinfected.
2. To **sterilize** means to kill all organism, whether harmful or not, and their spores present. In other words, sterilization is distinct from disinfection, sanitization, and pasteurization in that sterilization kills, deactivates, or eliminates all forms of life and other biological agents. Water to be injected into the body and used in chemistry, bust be sterile.

Most dwellings in a community-type society are cleaned using commonly produced materials, that wont harm the material upon which the product is used, and will disinfect and sterilize appropriately for a family dwelling:

1. Steam mop technology.
2. Hydrogen peroxide.
3. Vinegar.
4. Ozonated water.
5. Ethanol.

When it comes to disinfection and sterilization protocols associated with InterSystem team habitat services, most notably, production and medical, then there exists complex protocols, each with a complex of technologies and materials to achieve their objectives of sufficiently disinfecting and sterilizing habitat significant surfaces.

> **NOTE:** *All of these disinfecting and sterilizing processes require water, from the technological products used to produce the cleaner, to the final usage of the cleaner.*

8.4 Drying that which has been washed with water

There are various ways to dry surfaces that have been washed with water and water cleaning products, these include, but may not be limited to:

1. Drying in an ambient environment: The spectrum of ambient natural environmental exposures include: thermal sources of energy, sunlight, wind, humidity, pressure, etc.
2. Controlled drying through a machine.
   A. Control of ambient environmental factors.
      1. Fans, thermal sources, etc.
   B. For example, a home clothing dryer. Note: home dryer setups may operate more efficiently in their dryer function if a dry towel is added to the machines drying cycle. The two absorbs moisture from the fabrics, increasing the surface distribution of drying material without adding water.

9 Water transport and distribution units and processes

A.k.a., Artificial water transportation.

Water is transported around a habitat through a water transportation system (a.k.a., plumbing or hydraulics network/system) involving a network of pipes and pumps.

9.1 Pipe distribution of water

A.k.a., Water conduits, water channels, etc.

Pipes are generally round in shape and hollow. The hollow center is where water flows. The primary variables of pipes include:

1. Material composition.
2. Flexibility.
3. Permeable
4. Diameter.

9.2 Gravity-based transport of water

Water is moved around a water system through either pumping or gravity-flow through elevation differentials. Therein, elevation can be used to run distribution sub-systems through gravity pressure. Gravity transportation and distribution of water involves.

1. Positive pressure generated by gravity through a water tower. Great big tanks of water up on stilts. Pumps run all day to push water up into them, and when you open the faucet water flows downhill through the pipes and out of the tap. A tall tank is necessary to provide pressure, but it doesn't have to be big to provide quantity, as the water may be pumped up just before use.
2. Gravity flow and pump flow. A water service system could use one or the other, but generally they are used together.
3. There are other ways of providing pressure than gravity flow. A pump can provide positive pressure. Or a pump filling an internal airspace at the top of a tank could provide positive pressure. Pumps are located in "pump stations".
4. Reservoirs or when the water source is at a higher elevation create an environment where water flows downhill by gravity, through processing, into the mains distribution, with no pumps required. In some higher elevation geographic locations the water must be pumped up to the higher elevation to maintain enough pressure.
5. If there is too much pressure due to elevation, then sometimes the water processing system

downstream has to decrease pressure rather than increasing it.

6. Pumps and water towers work hand-in-hand. Without water towers, the pumps would have to operate continuously, even during low-demand periods. With water towers, the pumps pump water up into the towers, which then maintain pressure. As water is consumed, the level in the water tower drops until it reaches a certain point, which actuates a level switch to start up the pumps again. You can't have water towers without pumps. You can have pumps without water towers, but would always need to keep the pumps running (which is not generally practical).
7. Today speed drives control the speed of the pumps. As demand goes up the pumps speed up. Depending on the city the system pressure can run from 50 to 120 PSI.
8. Sometime buildings in a water distribution system have water regulators in them to protect the pipes of the building from the city's higher pressure.
9. However, it's pretty easy to provide the same constant, even, reliable pressure if you let gravity do it, or enclose the water in a tank which also contains a compressed gas like air -- a substance which is highly compressible.
10. You pump water into a tank, even in spurts, or compress air into a tank at irregular intervals, and the resulting gravity or air pressure evens out the flow to a workable level (e.g., positive-displacement pump).
11. When you have a centralized network around a series of main pumps, then the pressure will likely taper off as you approached the periphery of the network. Hence, elevated storage tanks and re-pump stations are necessary at strategic locations.
12. A clear well (a.k.a., clearwell) is an output/finished water storage area.

9.3 Pump-based distribution of water

A.k.a., Water pumps.

A pump is a device that moves fluids (liquids or gases). It is a device that moves fluid through a piping system by mechanical action. As such, it is a pressure (hydraulic) driven machine that converts mechanical energy to hydraulic energy. Pumps operate by a rotary and reciprocating mechanism, and they consume energy to move fluid. Water pumps move water (Read: transfer water) from one place to another. A water pump is an electromechanical device that pulls water from a water source (e.g., well, river, etc.) and pumps it into a water pipe system and/or fills a water tank. Water pumps supply the pressure needed to pressurize a plumbing system or fill a water tank with water from an outside source of water.

Pumps can have several functions, including but not limited to (*Variable speed*, 2021):

1. **Pressure pump** - provides water and creates water pressure for plumbing.
2. **Hot water recirculating pumps** - provide hot water for hot water outlets.
3. **Booster pump** - boosts water pressure in high-rise buildings.
4. **Pool pump** - provides water and circulation of water in pool and other aquatic areas.
5. **Hydronics pump (HVAC pump)** - provides for the circulation of HVAC fluid(s).
6. **Fire pump** - provides water (and water pressure) fire protection.
7. **Manufacturing water pump** - provides water (and water pressure) for manufacturing processes.

There are several additional types of pumps for most architectural structures:

1. **Sump pumps** - remove water that collects in basins from around a structure's foundation. Many are submersible sump pumps. They have a manual or semi-automatic motor housed in a water-tight compartment. This allows the pump to be fully immersed in liquid.
2. **Trash pumps** - designed for de-watering applications. These pumps help remove water that contains things like vegetation and sludge.
3. **Transfer pumps** - are utility pumps that move water from one location to another through hoses. They can handle everything from light aquarium applications to heavy de-watering.
4. **Boosting pumps** - add water pressure for washing services or lawn sprinkling. They can also increase pressure where low or inadequate water pressure is an issue. These pumps include water garden pumps.
5. **Lawn sprinkler pumps** - used to draw water from various sources to a garden sprinkler systems.
6. **Pond pumps** and **water garden pumps** - power water flow and circulation for decorative water features.
7. **Sewage effluent pumps** - pump liquids and semi-solids. They are usually located in a basement or a below-grade area. They are powerful enough to pump from a sewage basin up to the main sewer line for removal.
8. **Condensate pumps (evaporative cooler pumps)** - automatically remove condensation in high moisture areas. For example, they can remove collected condensation from furnaces or air