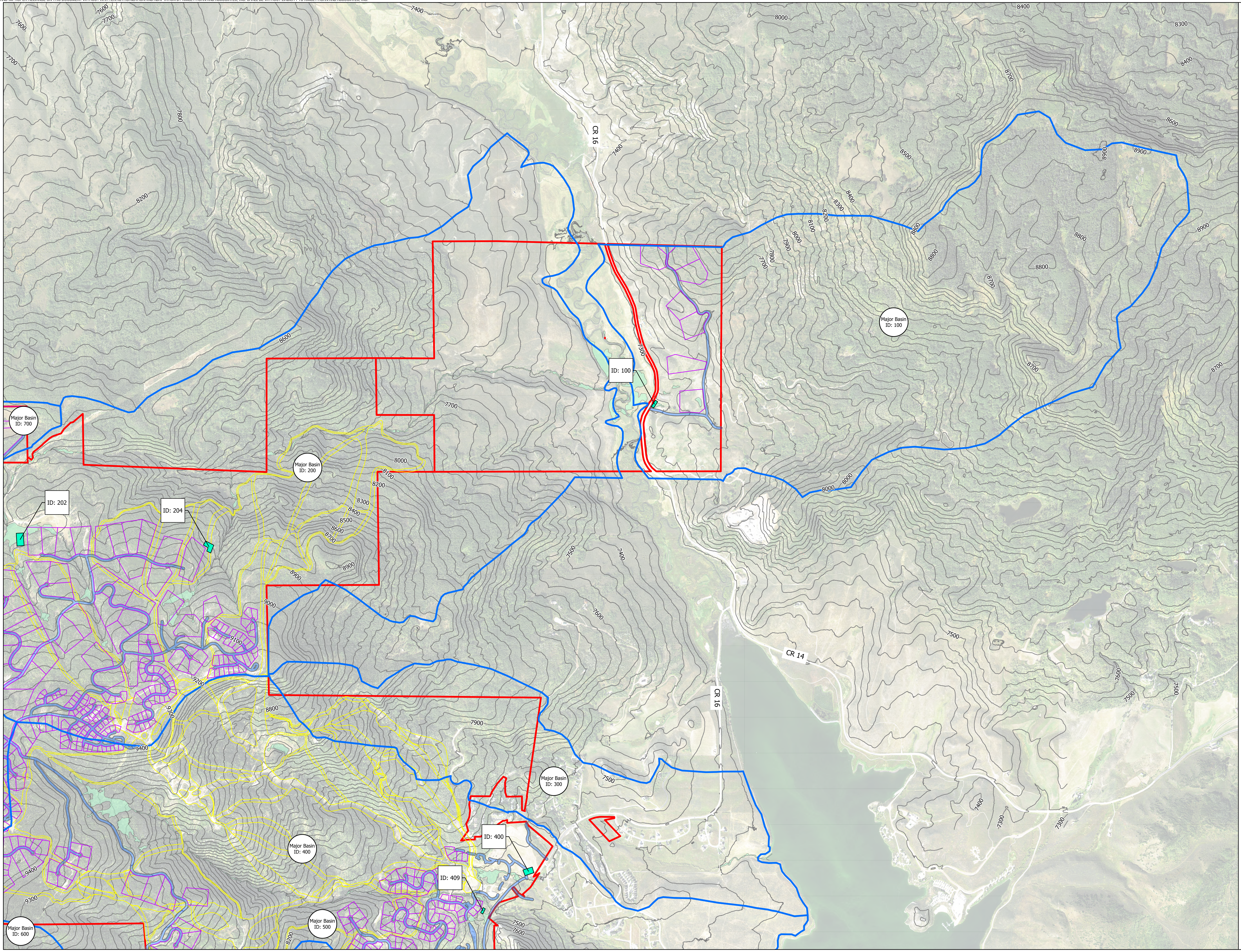

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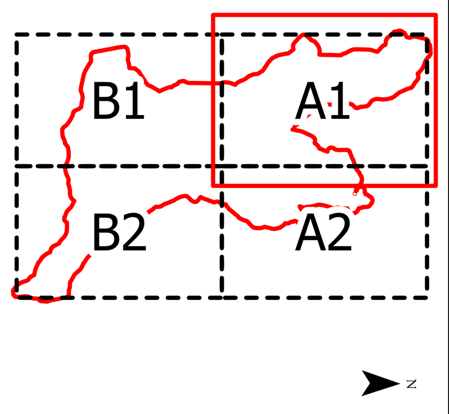


Legend

- Proposed Roads
- Proposed Ski Runs
- Property Line
- Existing 50ft Contours
- Proposed Major Basins

Preliminary Pond Locations

Alternate Pond Locations

- Wetlands
- Proposed Lot Boundary

MAJOR BASIN ID — Proposed Drainage Label

DETENTION POND ID — Proposed Detention Pond Label

N

0 500 1,000 2,000 Feet

Kimley»Horn

Engineering, Planning and Environmental Consultants
2 North Nevada Avenue, Suite 900
Colorado Springs, CO (719) 453-0180

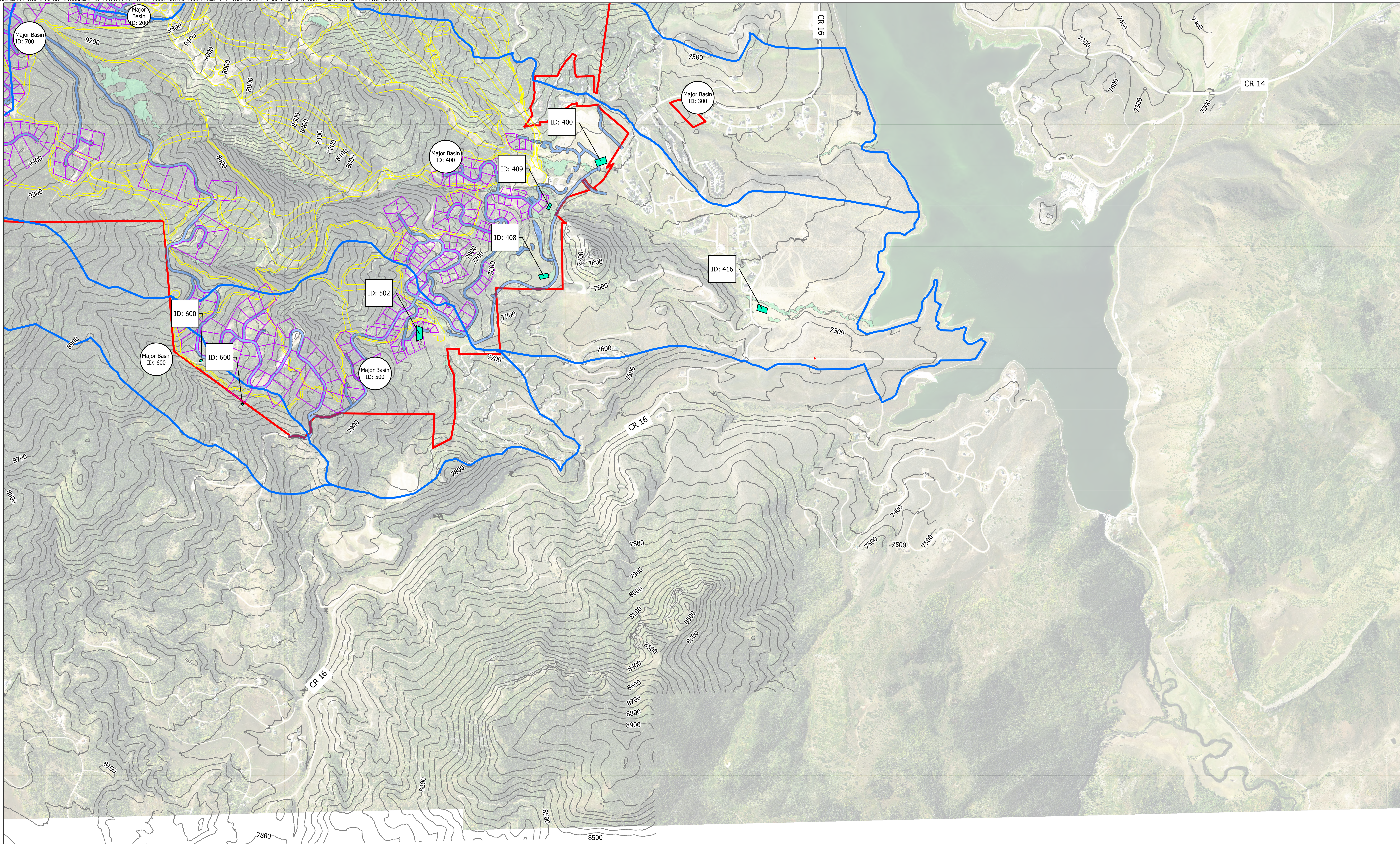
DESIGNED BY: SNM
DRAWN BY: TOS
CHECKED BY: BAH
DATE: 11/22/2024

STAGECOACH
DRAINAGE BASIN STUDY
PROPOSED POND LOCATION MAP

PROJECT NO.
196778000

DRAWING NAME
PROP_POND

Sheet: A1



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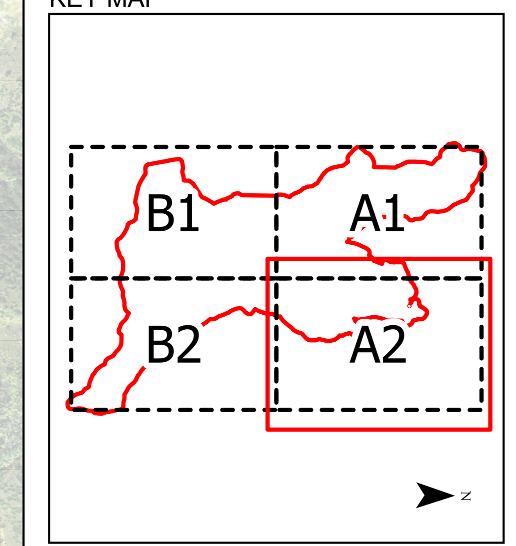

Legend

- Proposed Roads
- Proposed Ski Runs
- Property Line
- Existing 50ft Contours
- Proposed Major Basins

Preliminary Pond Locations

Alternate Pond Locations

- Wetlands
- Proposed Lot Boundary

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0 500 1,000 2,000 Feet

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DESIGNED BY: SNM
DRAWN BY: TOS
CHECKED BY: BAH

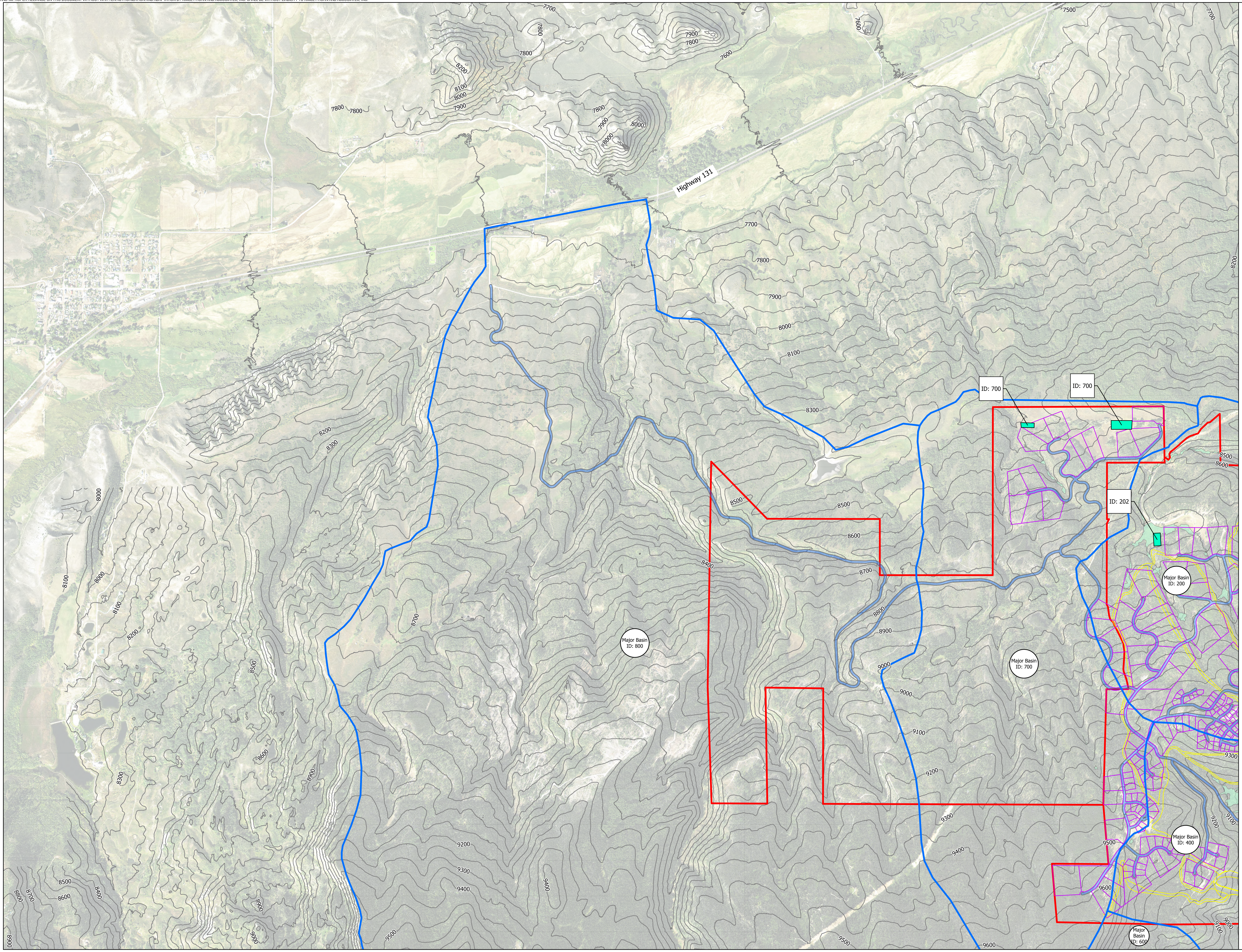
DATE: 11/22/2024

STAGECOACH
DRAINAGE BASIN STUDY
PROPOSED POND LOCATION MAP

PROJECT NO.
196778000

DRAWING NAME
PROP_POND

Sheet: A2



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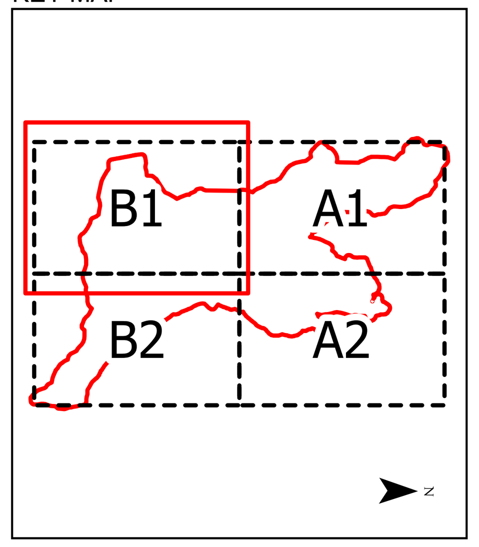

Legend

- Proposed Roads
- Proposed Ski Runs
- Property Line
- Existing 50ft Contours
- Proposed Major Basins

Preliminary Pond Locations

Alternate Pond Locations

- Wetlands
- Proposed Lot Boundary

MAJOR BASIN ID — Proposed Drainage Label

DETENTION POND ID — Proposed Detention Pond Label

0 500 1,000 2,000 Feet

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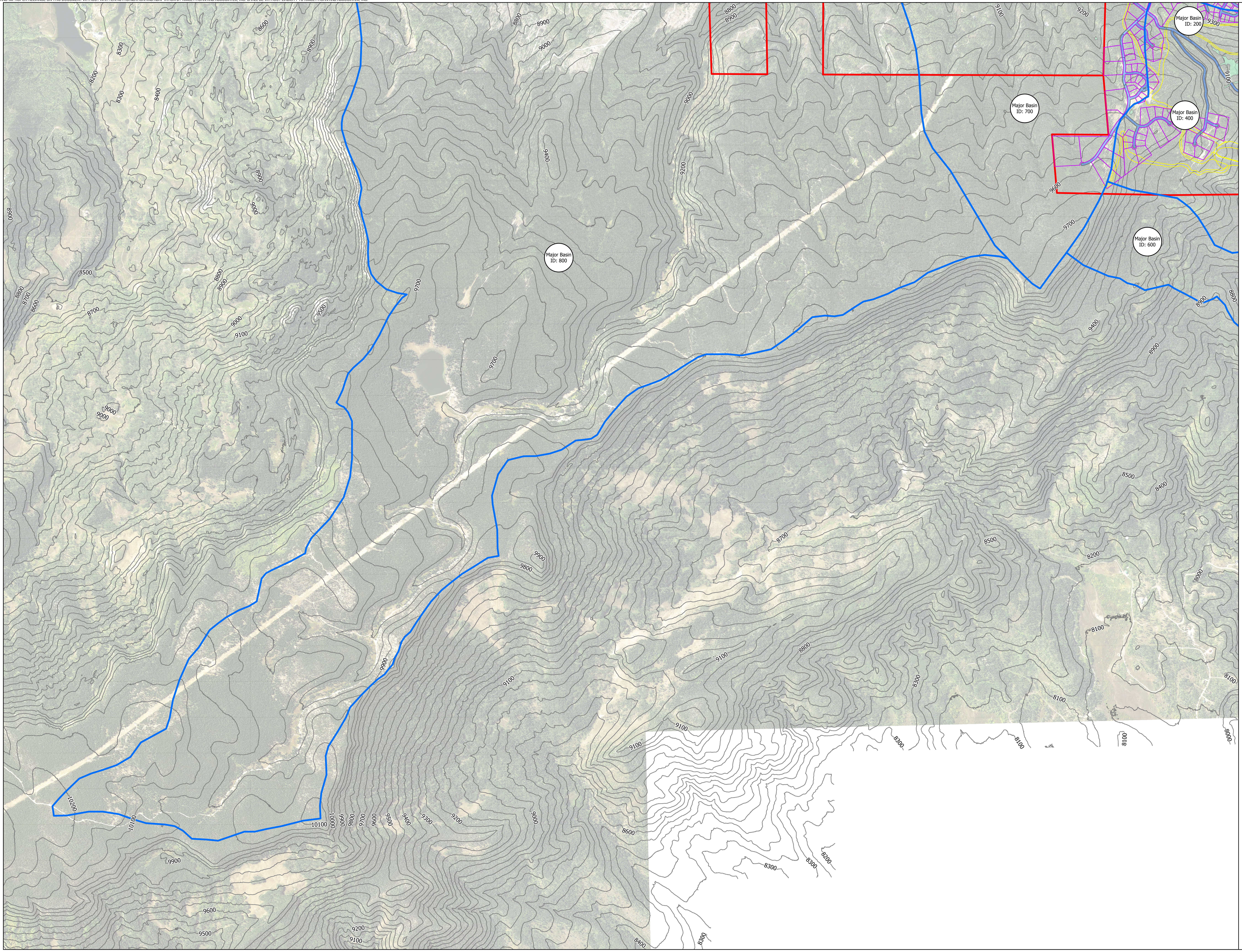
DESIGNED BY: SNM
DRAWN BY: TOS
CHECKED BY: BAH
DATE: 11/22/2024

STAGECOACH DRAINAGE BASIN STUDY
PROPOSED POND LOCATION MAP

PROJECT NO. 196778000

DRAWING NAME PROP_POND

Sheet: B1



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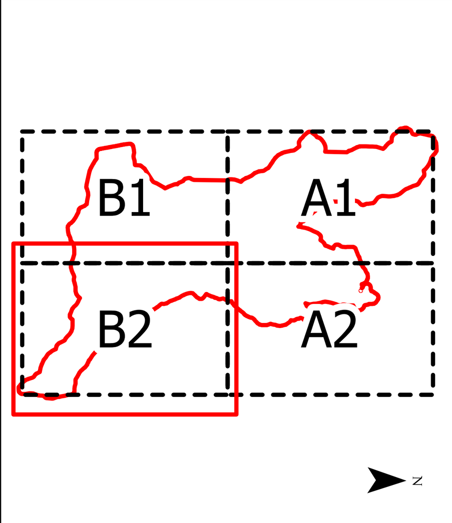

Legend

- Proposed Roads
- Proposed Ski Runs
- Property Line
- Existing 50ft Contours
- Proposed Major Basins

Preliminary Pond Locations

Alternate Pond Locations

- Wetlands
- Proposed Lot Boundary

MAJOR BASIN ID — Proposed Drainage Label

DETENTION POND ID — Proposed Detention Pond Label

0 500 1,000 2,000 Feet

Kimley»Horn

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CHECKED BY: BAH

DATE: 11/22/2024

STAGECOACH
DRAINAGE BASIN STUDY
PROPOSED POND LOCATION MAP

PROJECT NO.
196778000

DRAWING NAME
PROP_POND

Sheet: B2

APPENDIX E – WATER QUALITY BMP EXAMPLES

APPENDIX E –SCM/PCM TOOL KIT

1 Regional BMPs

1.1 Extended Detention Basin

<u>Description</u>

An extended detention basin (EDB) is a downstream feature often in a row of features. An EDB will detain and slowly release stormwater over a 40 hour drain time, allowing time for sediments to settle at the bottom. They are not designed to have a lot of water and can be referred to as "dry ponds". EDBs can be used in conjunction with full spectrum detention which provides flood control. Micropools are also used in conjunction with EDBs and allow water to flow through a submerged portion of a trash rack to reach the openings in the orifice.

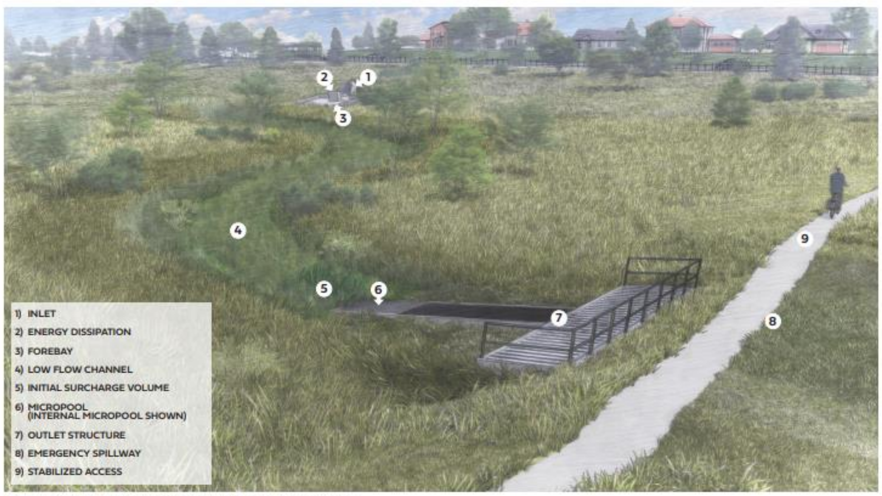

Figure EDB-1. Extended Detention Basin Components

TABLE EDB-2. EDB COMPONENTS

COMPONENT	INTENT
Inlet	Allows stormwater to enter the SCM. Maximize distance between inlet(s) and outlet to minimize short-circuiting and increase hydraulic residence time.
Energy Dissipation	Reduces the velocity and energy of runoff entering the SCM through roughness and/or structural measures to promote sedimentation in the forebay.
Forebay	Facilitates removal of trash and coarse sediments in an accessible location to reduce the frequency of sediment removal in the main body of the EDB.
Low Flow Channel	Conveys low flows from the inlets to the outlet structure, limiting the inundation area of frequent flows to facilitate maintenance operations.
Initial Surcharge Volume	Stores runoff from frequently occurring events in an area with hydrophytic vegetation adapted to frequent and prolonged inundation.
Micropool	Reduces potential clogging at the outlet by providing a flow path below the permanent water surface elevation to the orifice plate even when the trash rack becomes clogged above the water surface.
Outlet Structure	Releases the WQCV through control orifices over a 40-hour drain time and conveys runoff from larger events to downstream conveyance system.
Emergency Spillway	Discharges flows exceeding design events or flows during plugged outlet conditions to downstream conveyance system while protecting embankment stability.
Stabilized Access	Provides maintenance access to components of the EDB.

Source: MHFD – USDCM – Volume 3

<u>Operation and Maintenance (O&M):</u>

Maintenance for an EDB will include cleaning sediment and debris from its forebays, removing debris from outlet structure orifices and installing/cleaning trash racks (if necessary), vegetation management, and lastly removing any accumulated sediment from channels with low base flow. Micropools can also be used to help reduce clogging of any orifices.

1.2 Constructed Wetlands

Description

A constructed wetland includes a permanent pool of water that is above the designed capacity. This designed capacity will capture and slowly release the water quality capture volume (WQCV) over a period of 24 hours. The stormwater during each runoff event will mix with the permanent water, allowing for a reduced drain tome in comparison to the extended detention basin. A constructed wetland will also remove soluble pollutants through natural processes. A constructed wetland does require water rights since evaporation of the permanent pool will cause depletion in water flows downstream of what would be flowing past the wetland.

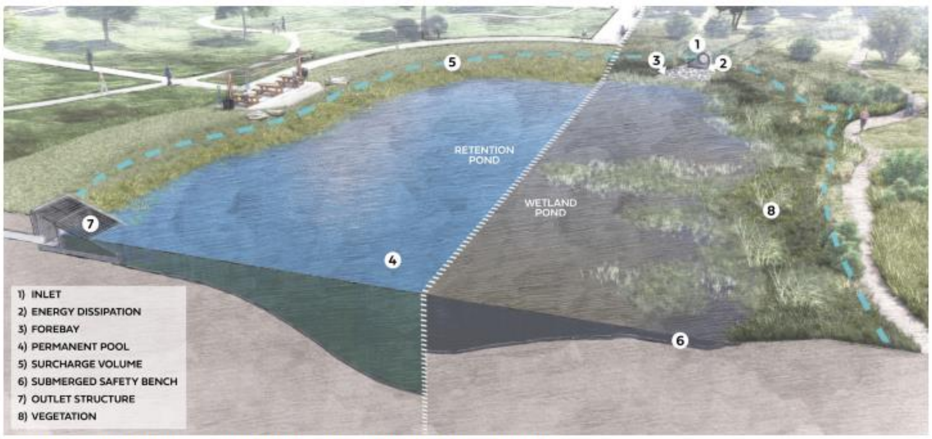

Figure RP/CWP-1. Retention Pond and Constructed Wetland Pond Components

TABLE RP/CWP-2. RP/CWP COMPONENTS

COMPONENT	INTENT
Inlet	Allows stormwater to enter the SCM.
Energy Dissipation	Protects against erosion when inlet is elevated above the permanent pool.
Forebay	Facilitates removal of trash and coarse sediments. This is the primary location for sediment removal.
Permanent Pool	Provides for quiescent sedimentation and biochemical processes that remove or transform pollutants between runoff events.
Surcharge Volume	Provides the WQCV for slow release through the outlet.
Submerged Safety Bench	Minimizes safety hazard of people inadvertently stepping into deep water or onto steep, wet slope.
Outlet Structure	Ensures slow release of water to provide treatment and reduce erosion in the receiving stream.
Vegetation	Filters runoff, provides biological uptake of pollutants, creates habitat, and mediates biochemical reactions in the soil.

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

A constructed wetland will need to be designed in such a way that there is pretreatment for trash and coarse sediment upstream of the permanent pool via a forebay that is elevated and accessible. Removal of sediment will need to occur periodically, maintaining a set depth and volume. This will reduce internal nutrient loading and help with algae blooms. These algae blooms can be managed through fertilizer management methods such as reducing the amount used, using phosphorus-free fertilizer, and using irrigation management. Lastly, when removing sediment from a constructed wetland, dewatering is typically required and should be considered. Inspect the channel at least annually.

APPENDIX E –SCM/PCM TOOL KIT

1.3 Retention Pond

Description

Retention ponds are very similar to constructed wetlands and requires slightly different maintenance. Retention ponds release the water quality capture volume over half the time, in 12 hours. A retention pond will still have a permanent pool, use natural processes to remove soluble pollutants, and require water rights.

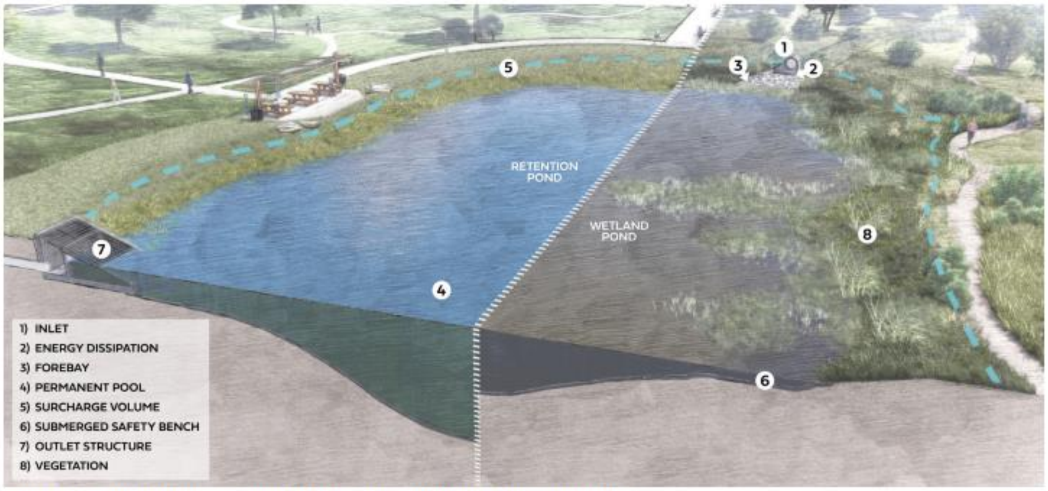

Figure RP/CWP-1. Retention Pond and Constructed Wetland Pond Components

TABLE RP/CWP-2. RP/CWP COMPONENTS

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Inlet	Allows stormwater to enter the SCM.
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Forebay	Facilitates removal of trash and coarse sediments. This is the primary location for sediment removal.
Permanent Pool	Provides for quiescent sedimentation and biochemical processes that remove or transform pollutants between runoff events.
Surcharge Volume	Provides the WQCV for slow release through the outlet.
Submerged Safety Bench	Minimizes safety hazard of people inadvertently stepping into deep water or onto steep, wet slope.
Outlet Structure	Ensures slow release of water to provide treatment and reduce erosion in the receiving stream.
Vegetation	Filters runoff, provides biological uptake of pollutants, creates habitat, and mediates biochemical reactions in the soil.

Source: MHFD – USDCM – Volume 3

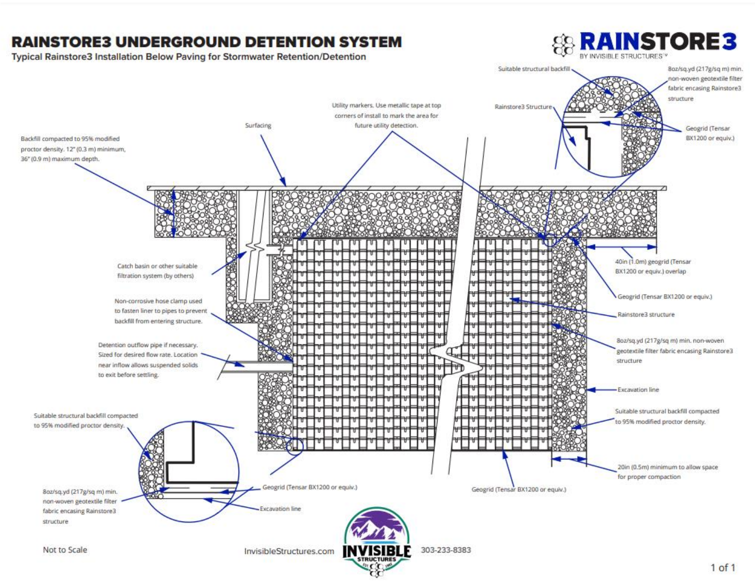
Operation and Maintenance (O&M)

Inspect the pond at least annually. Note the amount of sediment in the forebay and look for debris at the outlet structure. Remove debris and litter from the pond as needed. This includes floating debris that could clog the outlet or overflow structure. Mosquito control may be necessary if the BMP is located in proximity to outdoor amenities. The most effective mosquito control programs include weekly inspection for signs of mosquito breeding with treatment provided when breeding is found. These inspections and treatment can be performed by a mosquito control service and typically start in mid-May and extend to mid-September. The use of larvicidal briquettes or "dunks" is not recommended for ponds due to their size and configuration.

1.4 Underground BMPs

Description

Underground BMPs will vary as a BMP is a "best management practice". For this reason, an underground BMP may refer to any source control measure (SCM) that is primarily located beneath the surface. One example could be (but is not limited to) an underground infiltration system, which could be located beneath a parking lot.



Source: Invisible Structures

Operation and Maintenance (O&M):

Underground BMPs will typically require frequent inspections, starting quarterly in the first two years, twice a year after two years, and any time a storm event occurs over 6 inches. Here these BMPs will be inspected for debris and pollutants, using indicators such as visuals or odors to help accomplish this. Filters should be inspected twice a year and replaced at no more than three years of age. They should be inspected to the following MHFD criteria and by manufacturer specifications:

- If there is more than 4 inches of accumulated sediment on the vault floor.
- If there is more than ¼ inch of accumulation on the top of the cartridge.
- If there is more than 4 inches of standing water in the cartridge bay for more than 24 hours after the end of a rain event.
- If the pore space between media granules is full.
- If inspection is conducted during an average rainfall event and the system remains in bypass condition (water over the internal outlet baffle wall or submerged cartridges).
- If hazardous material release (automotive fluids or other) is reported.
- If pronounced scum line ($\geq$ 1/4" thick) is present above top cap.
- If system has not been maintained for three years.

2 Low Impact Development (LID) Techniques – Site Development

2.1 Receiving Pervious Area (RPA)

Description

The receiving pervious area is a space which receives runoff from the unconnected impervious area (UIA) and then allows that runoff to infiltrate. A good example of this would be a strip of vegetation within a parking lot that is at a lower elevation to allow runoff to drain to it. A lawn next to a sidewalk could be an example but, in many cases, will be a separate pervious area (SPA) since it will not receive runoff from the sidewalk. An RPA should be isolated from traffic, so it is very common to see a curb and gutter which is slotted or has another outlet structure to the RPA. Signage may also be used in the case where a curb and gutter would not work.

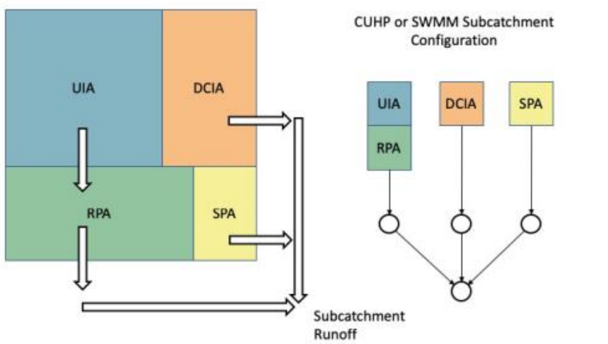


Figure 3-2. Four Component Land Use Model

Photograph 3-1. Separate Pervious Area (SPA) is permeable but does not receive runoff from impervious areas, such as the tree lawn in this photo. The drive and street are examples of DCIA.

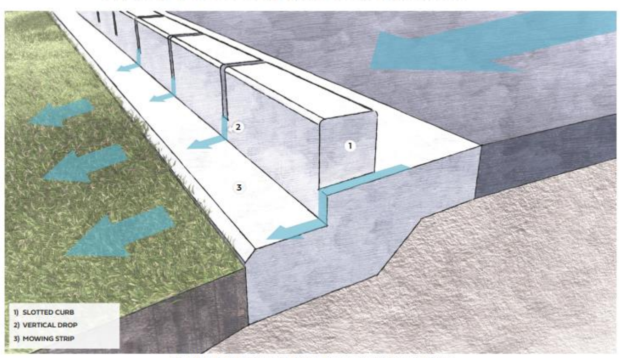


FIGURE 4-9. SLOTTED CURB DESIGN COMPONENTS

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

Cleaning an RPA is easy but can vary case by case. Most RPAs will be able to have routine trash pickup, mowing, and maintenance. In cases where it may become too wet to mow without causing damage to vegetation, underdrain systems may be installed to help with the moisture content of the soil. Snow considerations should also be made as snowmelt may cause salt and sand to be deposited into the RPA, which would need to be watched and maintained as to not negatively impact the area.

2.2 Permeable Pavement

Description

Permeable pavement refers to several techniques in which alternatives to paved areas are used to reduce the imperviousness of an area. The basic idea for permeable pavement is to allow water to filtrate into the developed area in which a typically paved area would runoff instead. Permeable pavements can be used as RPAs but are often designed to store the water quality capture volume (WQCV). One use for these could be in alleyways where RPAs aren't a feasible option. For permeable pavement to work properly, the area must have sheet flow. Typically, permeable pavement may also have other infrastructure associated with them, such as overflow weirs, where ponding may occur.

Types of permeable pavement that the MHFD includes are permeable interlocking concrete pavement (PICP), concrete grid pavement (CGP), porous gravel pavement (PGP) and reinforced grass pavement (RGP). The last of these, RGP, is used mostly in fire lanes or in area to reduce the impervious area but does not always provide treatment of the WQCV.

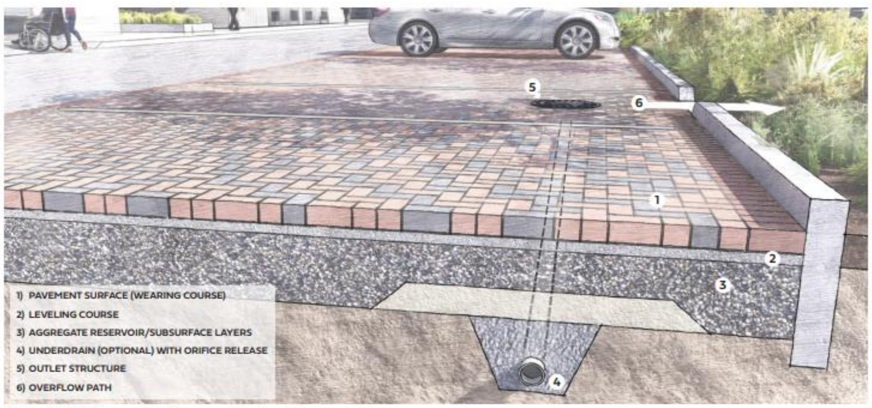


Figure PPS-1. Permeable Pavement System Components

Photograph PPS-3. PICP in downtown Ft. Morgan, CO. Note soldier course of light-colored pavers where PICP meets conventional pavement. Photo: SEH and the City of Ft. Morgan.

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

Permeable pavement is not typically suited for areas with lots of pollutants. Fast food, petrol stations, areas of high sediment runoff, and so forth. Since sediment can cause issues for permeable pavement, areas that store any loose materials, an area with a steep slope, or an area with little to no vegetation are not suitable for permeable pavement. Items such as leaves, or larger pieces of debris will need maintenance often to keep the permeable pavement functional. Snow removal is also important for permeable pavement, since sand should not be deposited on or around the area where the pavement lies. Since many factors can affect permeable pavement, periodic testing of the pavement's capacity to infiltrate is important to determine the need for maintenance.

APPENDIX E –SCM/PCM TOOL KIT

2.3 Green Roofs

Description

Green roofs are a type of rooftop systems that reduce imperviousness of an area, specifically though the use of vegetated systems. These will specifically reduce volumes and rates of runoff in an area. Green roofs are different than blue roofs, which act as stormwater detention areas. These two types of roofs can be combined, so some designs may have a “blue-green roof”. Green roofs have two subtypes, extensive and intensive. Extensive roofs allow there to be 6 inches of substrate, while intensive may have from 6 inches to several feet. Intensive roofs do this using a wide variety of plants and are more akin to gardens. Due to the lack of variety and depth of extensive roofs, they are typically cheaper and better suited for the structural design needs of a building.

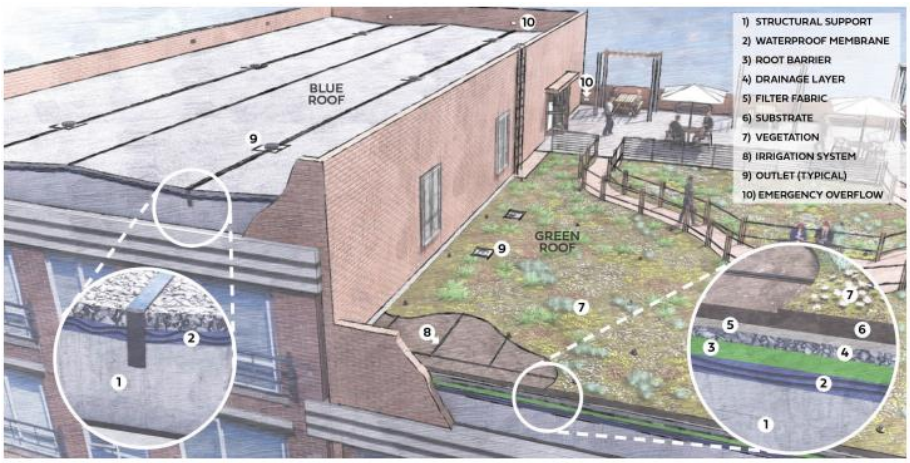


Figure GR-1. Green Roof and Blue Roof Components

TABLE GR-2. GR COMPONENTS

COMPONENT	INTENT
Structural Support	Roof structure that supports the substrate, vegetation, and live loads associated with rainfall, snow, people, and equipment.
Waterproof Membrane	Prevents water from entering the building.
Root Barrier	Protects the waterproof membrane by preventing roots from reaching the membrane. (Note: In some proprietary products, root barriers may be integrated into the product with the drainage layer.)
Drainage Layer	Drains the rooftop system to the outlet. This is sometimes an aggregate layer or a proprietary product.
Filter Fabric	This prevents fine soil and substrate from being washed out into the drainage layer.
Substrate (Growing Media)	Provides a growing media for the rooftop vegetation. Although the substrate is typically not “soil,” the terms *soil matrix, soil media* and *growth substrate* are sometimes used.
Vegetation	Provides evapotranspiration to reduce runoff volumes, aesthetic appeal, ecosystem services and a cooling effect for the building. Native/adapted, drought-tolerant grasses, perennials, and shrubs with relatively shallow root depths are possibilities for roof plantings.
Irrigation System	Supports vegetative health of green roofs. Even vegetation with low water requirements will require supplemental irrigation in the metro Denver area.
Outlet(s)	Provides outlet for detained flows to drain from the rooftop. Orifice controls are not required for green roofs designed to treat the WQCV but could be used to detain larger volumes. Orifice controls are required for blue roofs.

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

Pollutants and other debris can often impact the effectiveness of the irrigation and drainage systems. For this reason, cleanouts should be inspected and maintained frequently. Breaking up ice formations may be required for green roofs, but these more commonly impact blue roofs. Other weather-related factors may be of importance, as green roofs should be designed to be functional long term to avoid replanting and other maintenance items.

2.4 Grass Buffers

Description

Grass buffers are commonly used in conjunction with receiving pervious areas. Grass buffers are strips of dense vegetation, typically grass, which are designed to bring in sheet flows from developed areas. Grass buffers will provide filtration of sediment. Grass buffers are similar to grass swales but are designed for sheet flow rather than concentrated flow. They can be used together along with RPAs to create the most effective combination.

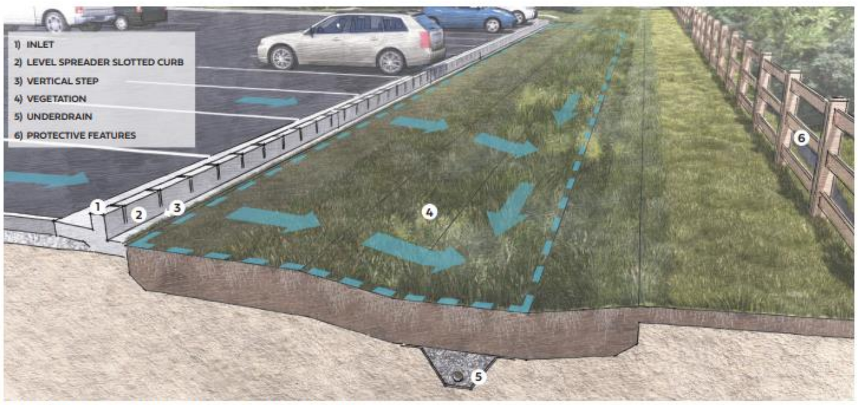


Figure RPA-1. Grass Buffer and Grass Swale Components

Photograph RPA-4. Grass buffers can be used to manage runoff from parking lots, multi-use paths, roadways, or roof areas, provided the flow is distributed in a uniform manner over the width of the buffer. Native grasses provide a more natural appearance. Photo: WWE.

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

Maintenance of grass buffers match other RPAs, including periodic maintenance and removal of sediment. See section 2.1 for more information.

2.5 Grass Swales

Description

Grass swales are dense areas of vegetation with a broad cross-section that bring in concentrated flow for infiltration. Grass swales may also reduce erosion in many cases. Grass swales are like grass buffers but work with concentrated flows instead of sheet flows. Grass swales may also use check dams to reduces slopes and ultimately velocities, encouraging settling of particles and increasing infiltration. Grass swales are also used in conjunction with RPAs and are the most effective when combined with both RPAs and grass buffers.

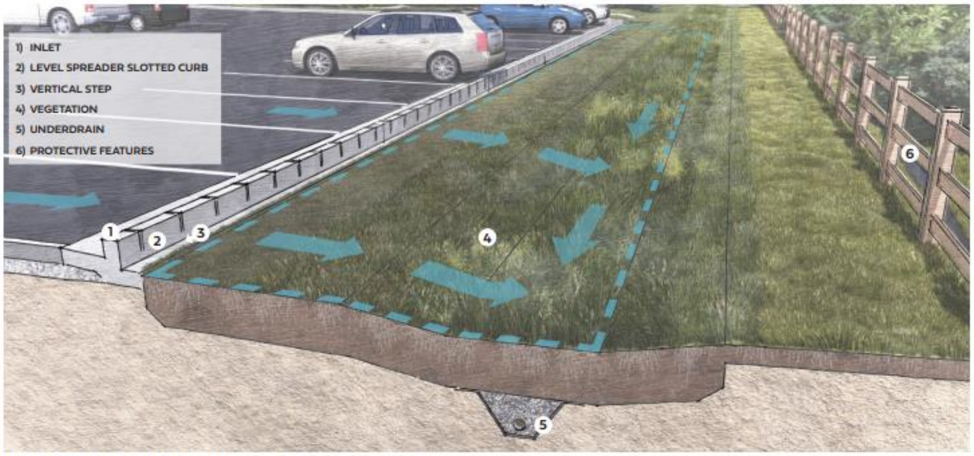


Figure RPA-1. Grass Buffer and Grass Swale Components

Photograph RPA-3. This grass swale provides treatment of runoff from a parking lot, portions of the building, and sidewalks at a healthcare facility. Photo: WWE.

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

Maintenance of grass swales match other RPAs, including periodic maintenance and removal of sediment. See section 2.1 for more information.

2.6 Bioretention (Rain Gardens)

Description

Bioretention systems are engineered landscapes which are depressed into the land, to capture and filter/infiltrate the water quality capture volume (WQCV). If designed and constructed properly, the MHFD strongly recommends the use of bioretention as a SCM due to their effectiveness in stormwater treatment, reduction in runoff volume and flow rates, and their benefits to the community in terms of green spaces. Bioretention system can also be designed for storm events larger than the WQCV can allow using the MHFD Storage Chapter.

Figure BR-1. Bioretention System Components

TABLE BR-2. BR COMPONENTS

COMPONENT	INTENT
Inlet	Allows stormwater to enter the SCM.
Forebay	Facilitates removal of trash and coarse sediments, providing pretreatment for the SCM.
Energy Dissipation	Minimizes potential for erosion of media surface.
Storage Volume	Provides temporary storage needed to attenuate design flows.
Engineered Media	Supports plant growth and reduces pollutants by filtering and through other biological treatment processes.
Vegetation	Helps maintain infiltration over time through root penetration of media, increases evapotranspiration and biological uptake of pollutants, aerates media, catalyzes soil ecology, and creates an attractive SCM.
Underdrain with Orifice Release	For partial and no infiltration systems, collects and slowly releases the WQCV over 12 hours to reduce erosion in the receiving stream and enhance treatment by increasing contact time with the media.
Outlet Structure	Safely conveys stormwater flows that exceed the design volume. For bioretention systems that detain the EURV and/or 100-year flow, surface outlet structures will have additional orifice controls for surface discharge rather than infiltration through the media.

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

To avoid clogging, the bioretention area requires a stable watershed. If there is a lot of sediment within the watershed, treatment should occur before the runoff reaches the bioretention area. Maintenance itself will need to be frequent, especially due to the aesthetic nature of bioretention. Since leaves and sticks can become an issue, both in terms of aesthetics and efficiency of the area, tree trimming could be included as one step in maintenance as to reduce this issue. Rock mulch can cause urban heat island effects, and is much harder to maintain and clean, so should be in places with resilient vegetation to assist with longevity of the design.

2.7 Constructed Wetland Channel

Description

A constructed wetland channel is very similar to a constructed wetland. The goal by using the vegetation in a constructed wetland channel is to slow down runoff, allowing more time for both biological growth and the settlement of sediment. A constructed wetland channel is best when a baseflow can be calculated and anticipated. Loamy soils will also need to be present, in order to allow plants to take root and grow.

Photograph CWC-1: Constructed wetland channels treat stormwater through straining, settling, and biological processes.

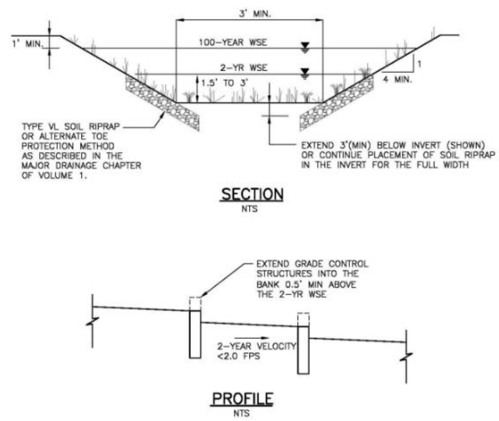


Figure CWC-1. Constructed Wetland Channel Plan and Section

Source: MHFD – Constructed Wetland Channel – T-9

Operation and Maintenance (O&M)

Constructed wetland channels require routine sediment removal. This will lie somewhere within the range of 10 to 20 years. Vegetation can be removed in order to keep the volume consistent throughout the years. This may cause more erosion to take place, so there is no set timeline for this maintenance to occur. Cattail removal will also have to occur more frequently and should take place during the late summer.

2.8 Sand Filters

Description

Sand filters are used to treat runoff through filtration, providing infiltration in cases when unlined systems are present. Runoff will collect during a storm event in a surcharge zone and infiltrate into the sand bed. An underdrain will release this captured water into channels, swales, or nearby storm drains. A sand filter may be used in cases in which bioretention would be used, with their main difference being their affinity for vegetation growth. A sand filter may also be designed for a 100-year flood storage volume but can be a challenge to maintain. In this case, sand filters should only be used if surface treatment is not feasible.

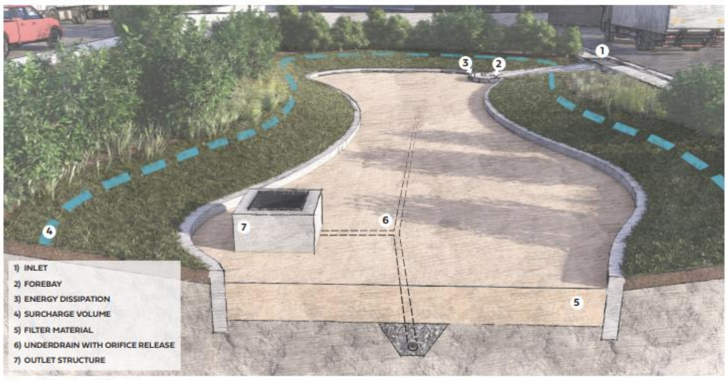


Figure SF-1. Sand Filter Components

TABLE SF-2. SF COMPONENTS

COMPONENT	INTENT
Inlet	Allows stormwater to enter the SCM.
Forebay	Facilitates removal of trash and coarse sediments.
Energy Dissipation	Minimizes potential for erosion of sand filter surface. Often incorporated into forebay.
Surcharge Volume	Provides temporary storage volume needed for attenuation of design flows.
Filter Material	Removes pollutants in runoff by filtration through porous media (sand).
Underdrain with Orifice Release	Collects and slowly releases the WQCV over 12 hours to reduce erosion in the receiving stream and enhance treatment by increasing contact time with the media.
Outlet Structure	Conveys stormwater flows that exceed the design volume.

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

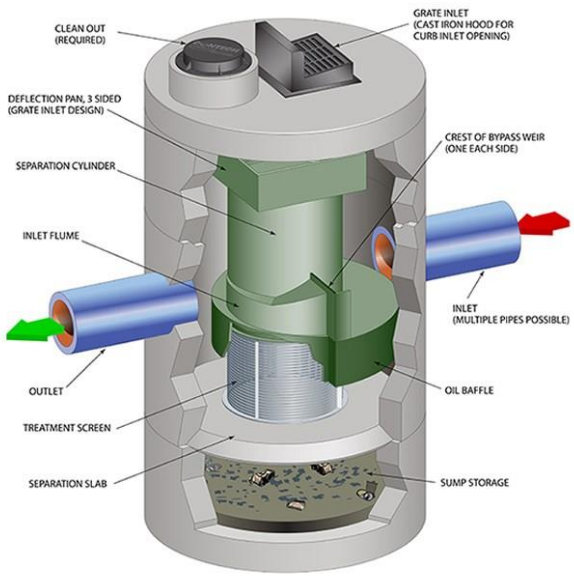
Coarse sediments and trash will be collected inside of forebays for removal during maintenance. Cleanouts will also be used during maintenance to allow for camera inspection as well as post-construction inspections.

3 Manufactured SCMs

3.1 Hydrodynamic Separator

Description

Hydrodynamic separators (HDSs) are a type of manufactured treatment devices (MTDs). MTDs goals are to reduce targeted pollutants. Hydrodynamic separators are a type of sedimentation MTDs, intended to use forces to suspend, trap and retain suspended sediments. Hydrodynamic separators are another good example of underground BMPs.



Source: S3 Stormwater Solution Source, LLC – Hydrodynamic Separators

Operation and Maintenance (O&M)

Hydrodynamic separators must be maintained frequently. This frequency is dependent on the volume of sediment in which the hydrodynamic separator can store. To remove the sediment, a vacuum must be used. Vacuuming should occur at least once annually and more frequently based on inspections as per underground BMP requirements (see section 1.4).

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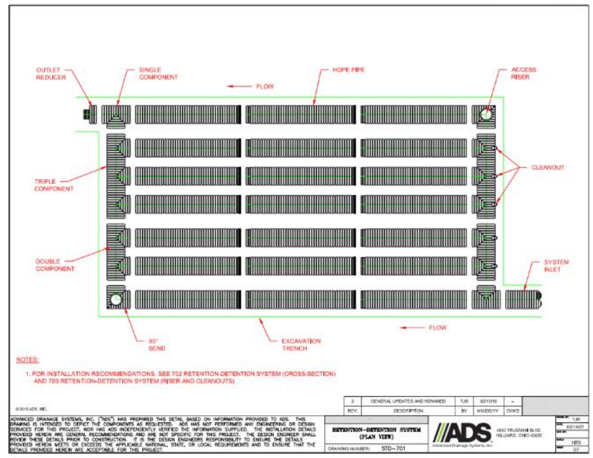
3.2 Underground Detention Chambers/Vaults

Description

Underground detention vaults are one form of underground BMP from section 1.4. These vaults or chambers are used to store runoff from a storm to manage and control the volume. The use of these detention facilities is to help with the effects of runoff like erosion and flooding. Since these facilities are located below grade, any risks associated with open ponds are reduced. There are two types of underground detention vaults, concrete chambers and HDPE pipe. The concrete chambers and HDPE pipe can be both infiltration based, or detention based. The HDPE pipe has a design life of at least 75 years.

Source: StormTrap – Ohio Department of Transportation



ADS – Landmax Stormwater Management System

Operation and Maintenance (O&M)

Maintenance varies depending on solution and company, but many have designed solutions to assist with the underground BMP guidelines. See section 1.4 for more information on underground BMP pollutant removal and maintenance.

4 SCM/PCMs and WQ Measures for Linear Roadways

4.1 Sand Filters

For all sand filters, please refer to section 2.8 for basic information.

No-Infiltration Sand Filters

Description

No-infiltration sand filters include an underdrain to the typical sand filter. This underdrain has an impermeable liner preventing infiltration of stormwater into the soils before the sand filter. These should be used for three reasons:

- The site could receive toxic pollutants via stormwater runoff and infiltration could result in contamination of groundwater.
- The site is located over contaminated soils and infiltration could mobilize these contaminants.
- The site is located over potentially expansive soils or bedrock that could swell due to infiltration and potentially damage adjacent structures.

Source: CDOT – Drainage Design Manual (2019) – Chapter 16

The no-infiltration sand filter should be made of a PVC geomembrane layer. It should be at least 30 mm thick and should extend to the top of the underdrain layer. Lastly, it should have 9 to 12 inches of cover wherever attached to a wall to help with UV deterioration.

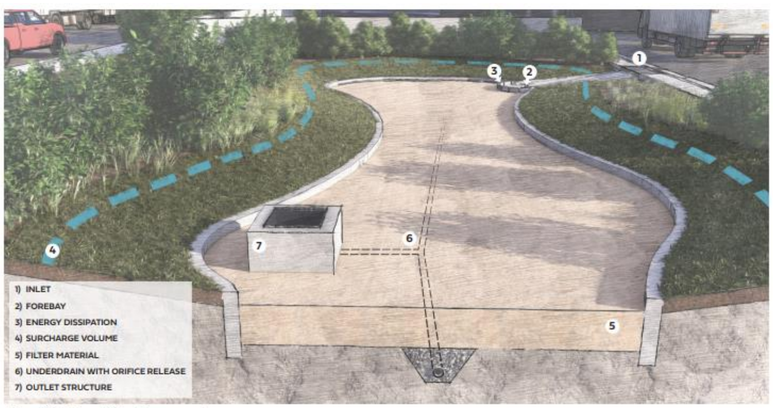


Figure SF-1. Sand Filter Components

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

Sand filters should be inspected annually or semi-annually to identify clogs or excess sediment. The infiltration rate should also be tested to determine if the surface material will need to be replaced. Other maintenance will match that of a typical sand-filter. Refer to section 2.8 for pollutant removal and general information.

Partial Infiltration Sand Filters

Description

Similarly to the no-infiltration sand filter, the partial infiltration sand filter includes an underdrain to the sand filter. Unlike it though, the partial infiltration sand filter does not include any type of impermeable liner, allowing some infiltration to occur. For CDOT, this is the most likely filter as in many cases the soil cannot drain the WQCV in 6 hours or less. In partial infiltration sand filters, the outlet structure should drain the design volume over a period of 12 hours.

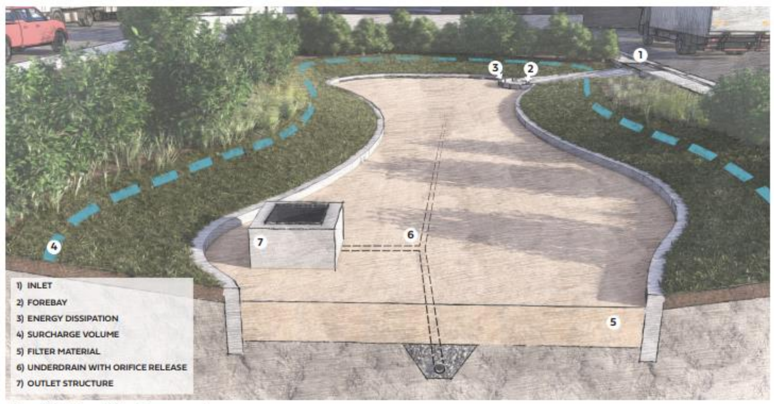


Figure SF-1. Sand Filter Components

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

Sand filters should be inspected annually or semi-annually to identify clogs or excess sediment. The infiltration rate should also be tested to determine if the surface material will need to be replaced. Other maintenance will match that of a typical sand-filter. Refer to section 2.8 for pollutant removal and general information.

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Full Infiltration Sand Filters

Description

A full infiltration sand filter will have all the water within the WQCV drain within 6 hours as required. This system leads to the longest-term functionality, as another drain and liner are not necessary. In certain cases, an outlet drain may be inserted with a gate or value to allow follow and drainage to be changed at any point in time.

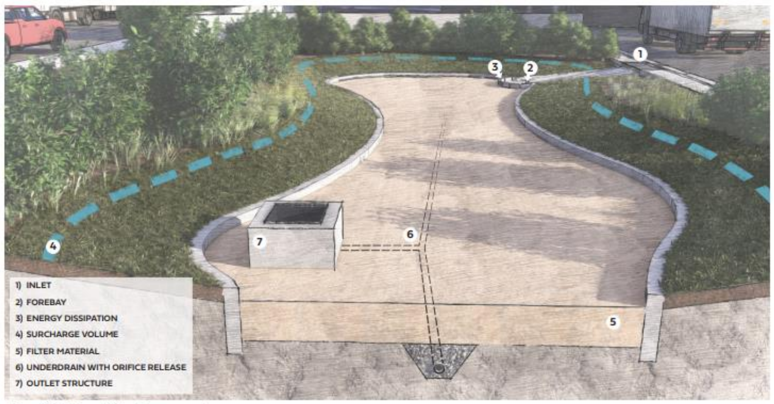


Figure SF-1. Sand Filter Components

Source: MHFD – USDCM – Volume 3

Operation and Maintenance (O&M)

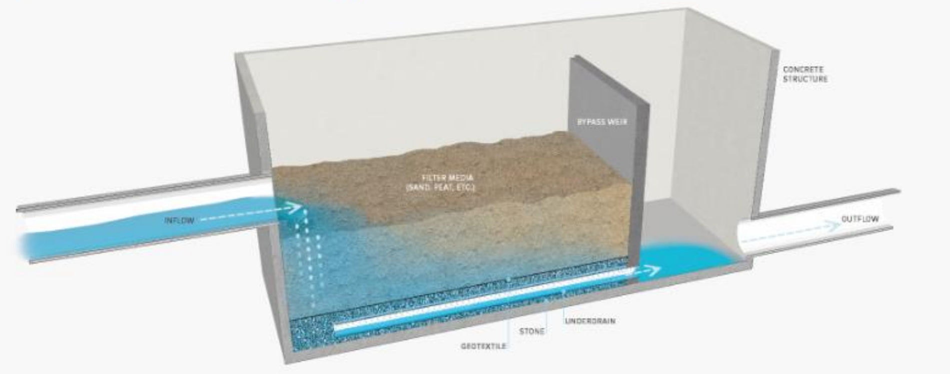
Sand filters should be inspected annually or semi-annually to identify clogs or excess sediment. The infiltration rate should also be tested to determine if the surface material will need to be replaced. Other maintenance will match that of a typical sand-filter. Refer to section 2.8 for pollutant removal and general information.

4.2 Media Filter Permeable Pavement

Description

Media filter drains are the original concept behind media filter permeable pavement. Media filter drains are used for treatment of sheet flow. An important note to be aware of is that another name for these is also ecology embankment. Media filters can only be used where the slope is at 4H:1V or less and if roadway is at a longitudinal slope of 5% or less. This media filter in tandem with a typical permeable pavement creates the media filter permeable pavement. Below is a visual representation of how media filters work, as well as the image used in section 2.2 to show how permeable pavement works.

Figure 4.9-1: Media Filter with Typical Features



Source: Philadelphia Water Department – 4.9 Media Filters

Operation and Maintenance (O&M)

Maintenance will be like that of permeable pavement in section 2.2. Extra time will need to be spent to make sure the media filter is not damaged during routine inspections.

4.3 Dispersion Berms / Level Spreaders

Description

Dispersion berms are intended to replicate the effect of natural dispersion. To accomplish this a conveyance system will bring concentrated flows to a level spreader which directs runoff into a dispersion area, mimicking sheet flow. The dispersion area typically requires compost-amended soils and denser than normal vegetation to accomplish this.

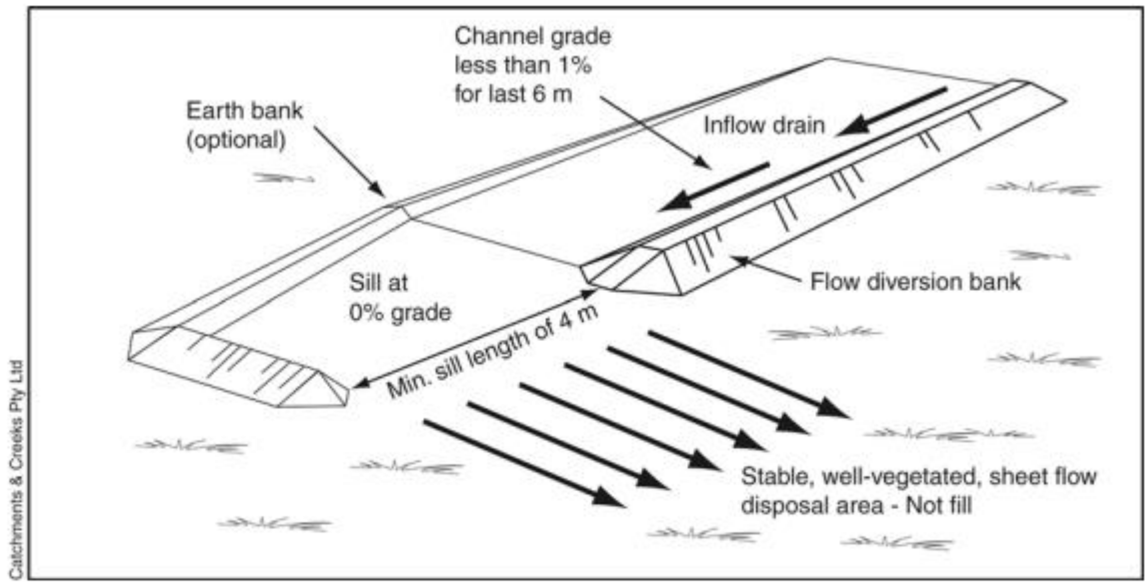


Figure 2 – Typical layout of level spreader

Source: Catchments & Creeks Pty Ltd – Level Spreaders

Operation and Maintenance (O&M)

Trash and debris need to be removed routinely, and moving and removal of vegetation will be required. Removing deposited sediments will also be necessary, ensuring an even distribution over areas of flow and dispersion.

4.4 Soil Amendments

Description

Soil amendments are used to make soil more suitable for the growth of vegetation. These include items such as soil conditioners, soil fertilizers, and compost amendments. Compost is often used as a soil conditioner due to its high cation exchange capacity, trapping and dissolving heavy metals. It will also remove oil, grease, and other items from any highway runoff.

Example of Soil Amendments - Fertilizers

Source: Michigan State University – MSU Extension Agrifood Safety – Soil Amendments

Operation and Maintenance (O&M)

Maintenance includes typical trash removal from any area with soil amendments. To do this, it is important to not impact the soil with any heavy machinery, which would affect infiltration and water holding capacity. Soil amendments can clog soil with sediments, after which vegetation and soil would also need to be replaced. After large storms or long durations of wet events, soil should be observed for excessive ponding, indicating if the soil should be replaced.

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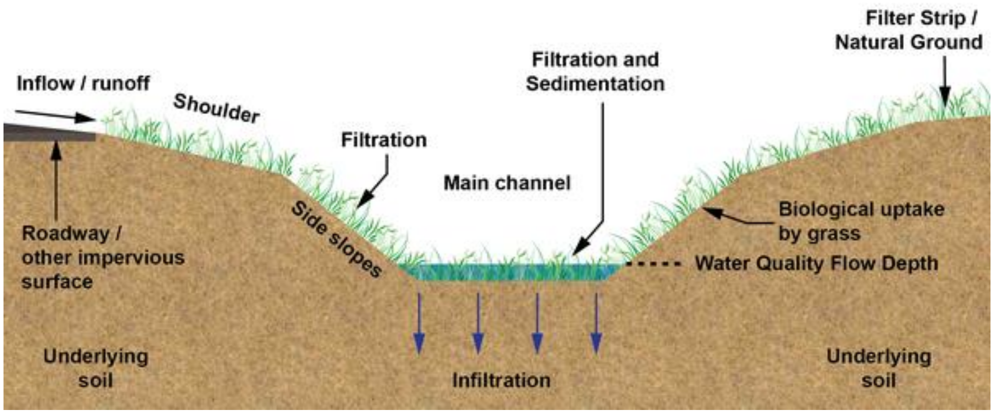
4.5 Treatment Swales

Description

Treatment swales are open channels that are shallow and above grade that aid in the treatment in stormwater runoff. To achieve this they use sedimentation, filtration and infiltration as water is moved through a vegetated surface and the topsoil layer. Vegetation is required for any hydrologic soil group unless the group is classified as A. The roots of the vegetation in groups B, C and D help the water infiltrate into the ground. Underdrains may be installed, only if the swale does not meet the design requirements.



Source: North Carolina State University – Swale Terminology for Urban Stormwater Treatment

Operation and Maintenance (O&M)

Typically, swales are low cost, low maintenance, and are effective at pollutant removal. In most cases, trash and debris need to be removed periodically. Mowing along the channel may be necessary if the bottom vegetation is too dense but should not occur unless necessary. Mowing the edges of the swale along the road or outside of the invert is recommended.

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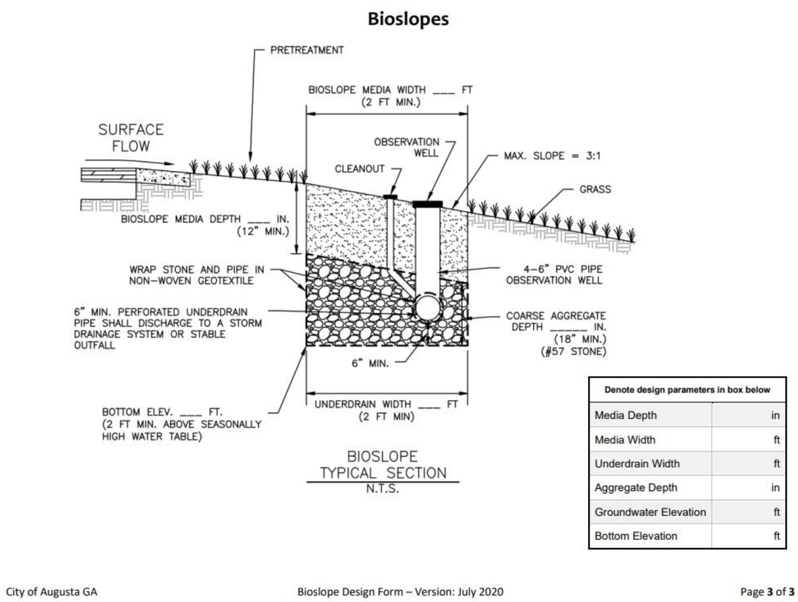
4.6 Bioslopes/Bioretention/Biofiltration Swales

Description

These are types of permanent water quality control measures, and they require a lot of maintenance. Their vegetation needs to be closely managed, specifically by a licensed landscape architect to ensure that the structures are properly constructed and maintained. Irrigation will need to be installed as well if base flows are not present.



Source: City of Augusta GA – Bioslope Design Procedure Form

Operation and Maintenance (O&M)

These structures require that an operation and maintenance plan is created for each individual or group. This plan is to be created by the licensed landscape architect.

5 Regenerative Stormwater Conveyance (WV DEP)

Description

Regenerative Stormwater Conveyance (RSC) is an innovative approach to provide stormwater treatment, infiltration, and conveyance within one system. It has been used as an ecosystem restoration practice for eroded or degraded outfalls and drainage channels. RSC utilizes a series of shallow aquatic pools, riffle weir grade controls, native vegetation and underlying sand and woodchip beds to treat, detain, and convey storm flow. It can be used in places where grades make traditional stormwater practices difficult to implement. RSC Systems combine features and treatment benefits of Swales, Infiltration, Filtering and Wetland practices. In addition, they are designed to convey flows associated with extreme floods (i.e., 100-year storm) in a non-erosive manner, which results in a reduction of channel erosion impacts commonly encountered at conventional stormwater outfalls and headwater stream channels.

RSC can be used to: Manage the first one inch of rainfall on-site, Reduce pollutant loads to meet water quality targets (total maximum daily loads or TMDLs), Meet partial or full storage requirements for local stormwater detention standards, Retrofit existing developed areas, especially areas with eroded and degraded (entrenched) outfalls, ditches, and ephemeral or intermittent gullies that discharge to waterbodies RSC can be blended into the landscape design for many sites.

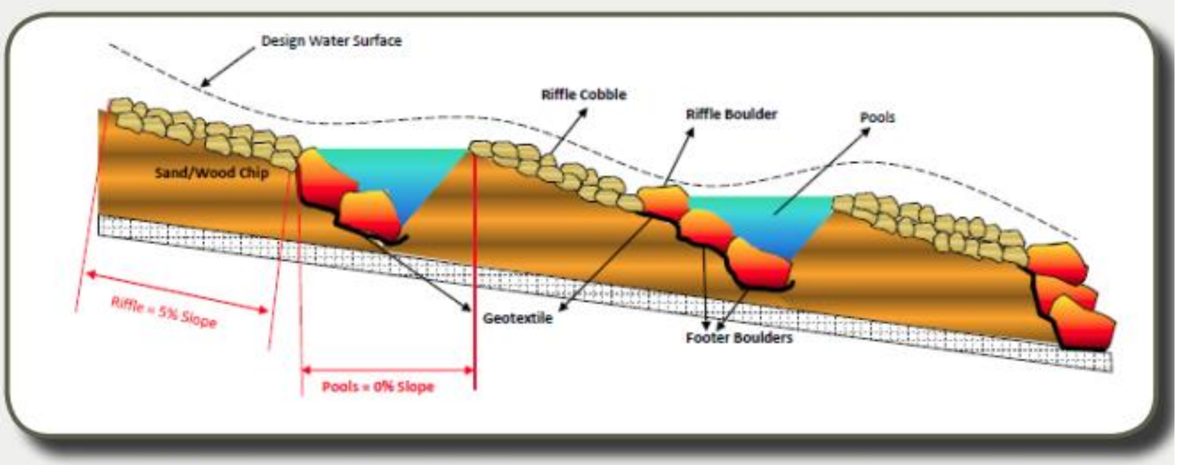


Figure RSC-2. Schematic Profile for Regenerative Stormwater Conveyance System (Source: Anne Arundel County, 2011)

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Operation and Maintenance (O&M)

Maintenance Tasks	**Frequency**
▪ For the first 6 months following construction, the practice and drainage area should be inspected at least twice after storm events that exceed 1/2 inch of rainfall. ▪ Check for erosion or "end-cutting" of weirs and riffle structures. ▪ Check for stable water levels in pools. ▪ Conduct any needed repairs or stabilization. ▪ Inspectors should look for bare or eroding areas in the contributing drainage area or around the RSC channel, and make sure they are immediately stabilized with grass cover. ▪ One-time, spot fertilization may be needed for initial plantings. ▪ Watering is needed once a week during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall. ▪ Remove and replace dead plants. Up to 10% of the plant stock may die off in the first year, so construction contracts should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.	Upon establishment
▪ Routine maintenance of vegetation: weeding, pruning, etc. ▪ Trash removal	Approximately 4 times a year
▪ Add reinforcement planting to maintain desired the vegetation density ▪ Remove any dead or diseased plants ▪ Stabilize the contributing drainage area to prevent erosion	As needed
▪ Conduct a maintenance inspection ▪ Check structural stability of weirs, riffles, pools; check for desired water level in pools ▪ Prune trees and shrubs ▪ Remove invasive plants using recommended control methods ▪ Remove sediment in pre-treatment cells and inflow points	Annually
▪ Remove sediment in pools if necessary ▪ Repair any structural damage to weirs, riffles, pools, or tie-in to downstream channel	Once every 2 to 3 years

Source: WV Stormwater Management & Design Guidance Manual

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ADS – Landmax Stormwater Management System – 701 Retention-Detention System Plan View
https://assets.adspipe.com/m/1116179ecc6d5382/original/701-Retention-Detention-System-Plan-View-Detail.pdf?_gl=1*1ik5uzj*_gcl_au*NDg4Mjk0ODMwLjE3MjEyMzgzMDY.*_ga*MjM2OTA2ODYyLjE3MjEyMzgzMDY.*_ga_1TPLC9D3R7*MTcyMTIzODMwNi4xLjEuMTcyMTIzOTU0Ny4yNS4wLjA.

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https://www.austieca.com.au/documents/item/312

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https://www.augustaga.gov/DocumentCenter/View/14862/H2-DPF_Bioslope

Invisible Structures - Rainstore3 Underground Detention System Detail
https://invisiblestructures.com/media/q4fnoax4/rs3detentiondetail24.pdf

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North Carolina State University – Swale Terminology for Urban Stormwater Treatment
https://content.ces.ncsu.edu/swale-terminology-for-urban-stormwater-treatment

Pennsylvania Stormwater Best Management Practices Manual – Chapter 6
https://greenport.pa.gov/elibrary/GetDocument?docId=7662&DocName=CHAPTER%206.4.10%20BMP%20INFILTRATION%20BERM%20AND%20RETENTIVE%20GRADING.PDF%20%20%3Cspan%20style%3D%22color%3Agreen%3B%22%3E%3C%2Fspan%3E%20%3Cspan%20style%3D%22color%3Ablue%3B%22%3E%3C%2Fspan%3E

Philadelphia Water Department – 4.9 Media Filters
https://water.phila.gov/development/stormwater-plan-review/manual/chapter-4/4-9-media-filters/#:~:text=Media%20filters%20(also%20referred%20to,%2C%20hydrocarbons%2C%20and%20other%20pollutants.

S3 Stormwater Solution Source, LLC – Hydrodynamic Separators
https://www.s3usa.com/products/treatment/hydrodynamic-separators

StormTrap – Ohio Department of Transportation
https://stormtrap.com/project/ohio-department-of-transportation-cso-reduction-project/

West Viriginia Stormwater Management & Design Guidance Manual – Regenerative Stormwater Conveyance System (RSC)
https://dep.wv.gov/WWE/Programs/stormwater/MS4/Documents/Specification_4.2.7_Regenerative_Stormwater_Conveyance_WV-SW-Manual-11-2012.pdf