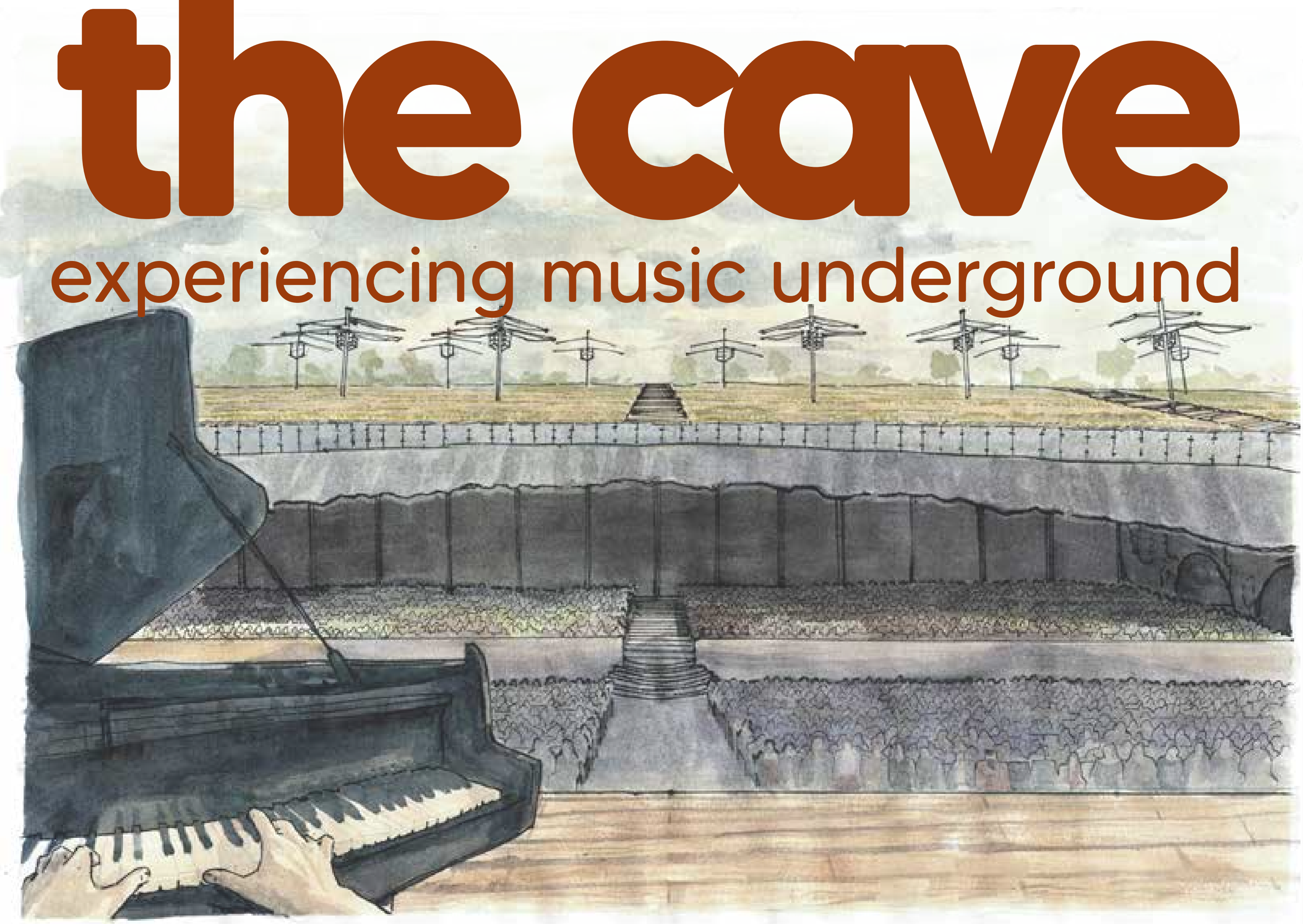
the cave
experiencing music underground



Project portfolio - ACEX15
Bachelor project in Architecture and Technology
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Avdelningen för arkitekturens teori och metod
CHALMERS TEKNISKA HÖGSKOLA
Göteborg, Sverige 2026

Background

Designing an outdoor concert pavilion for 13,000 visitors involves more than accommodating performance and audience. The project investigates how architecture can shape a collective acoustic experience at the scale of landscape.

Developed as part of an architectural competition, the proposal explores the relationship between sound, structure, movement, and topography. Acoustic performance became a primary generator of form, informing both the spatial organization and the geometry of the pavilion itself.

This booklet documents the development of the project – from early site analysis and acoustic studies to conceptual iterations and the final proposal. It reflects an approach in which technical performance and architectural expression are treated as inseparable parts of the same design process.

Contents

Competition brief

A city orchestra wishes to construct a new 13,000-seat music pavilion with covered and lawn audience seating to serve as its summer home.

The music pavilion will have a variety of programing acts, with the orchestra as a resident company during the summer season. Additionally, the pavilion will host touring acts, like pop and rock shows to balance out revenue stream in support of the orchestral program. The pavilion should be sized to accommodate 3,000 seated audience members under a roof and 10,000 audience members in an open lawn. The anticipated number of audience members is 7,500 people for orchestra performances and 13,000 people for touring acts. The orchestra desires a stage environment that supports natural, unamplified ensemble hearing among musicians. Amplification via an electro-acoustic sound reinforcement system will be used to provide coverage for both seated and lawn audiences. The project site has a natural slope and provides several different locations and orientation options. Location and orientation should be considered for the impact of event sound on the surrounding communities. The site is surrounded by a river to the north, a state highway to the south and state roads to the east and west. There is a major 6-lane interstate located 200 feet to the east of the site. Sound levels measured from the interstate have been provided and must be taken into consideration. Please see attached site plan.

Back of house (BOH) support space will be required; some spaces will be acoustically sensitive. Solo dressing rooms will also serve as practice rooms. Mechanical, Electrical, Plumbing (MEP) services will be required to serve BOH and stage spaces. Considerations should be made on the impact of noise and vibration generated from building systems and equipment for on-stage hearing, microphone pickup, and environmental impact to nearby residential zones.

Program Details

The following section is the architectural program statement for the pavilion which defines the building (for the purposes of this design competition) as desired by the orchestra.

Pavilion:

Audience Seating: 3,000 seated audience members under a roof designed to provide light weather protection from intense sun or rain events. 10,000 lawn audience members.

Stage: Approximately 5,000 ft2 (460 m2) with depth of approximately 50 ft (15 m). To accommodate up to 100 orchestra members and occasionally 150 additional choir members for performance and rehearsal.

Orchestra Locker Rooms: To accommodate up to 100 orchestra members and store instrument cases during rehearsal and performance.

Loading Dock: Easy access to stage for scenery and other materials being transported in/out. To accommodate at least 2 touring trucks.

Dressing Rooms: One star dressing room, approximately 300 ft2 (28 m2), able to house a piano. Six solo dressing rooms, approximately 200 ft2 (19 m2) each. Dressing rooms may also be used as music practice rooms.

Green Room: One multipurpose Green Room, approximately 700 ft2 (65 m2), to accommodate performers and meet and greets.

Office Space: Four-office suite for facility’s technical staff, approximately 125 ft2 (12 m2) each. Two offices for touring staff, approximately 100 ft2 (9 m2) each.

BOH Restrooms: Approximately 2000 ft2 (186 m2) total; can be split around BOH.

Storage Rooms: Approximately 6000 ft2 (558 m2) total; can be split around BOH. At least one room to accommodate easy access to stage for piano storage.

Mechanical Equipment Room (MER): To primarily house air handlers, chiller, electrical equipment, etc. serving BOH and stage,

Site Noise Considerations
Touring performances will be mixed to achieve 95 dBZ for all members on the lawn seating. Measured highway traffic noise levels at the edge of the site closest to the highway in octave frequency bands are tabulated below:

*Each set of levels represents the range of levels observed in each octave frequency band for a 20-minute period during heavy, late afternoon traffic. Levels indicated are believed to represent realistic "worst case" environmental sound levels at the site. Measurements were made at the edge of the site that is closest to the highway.

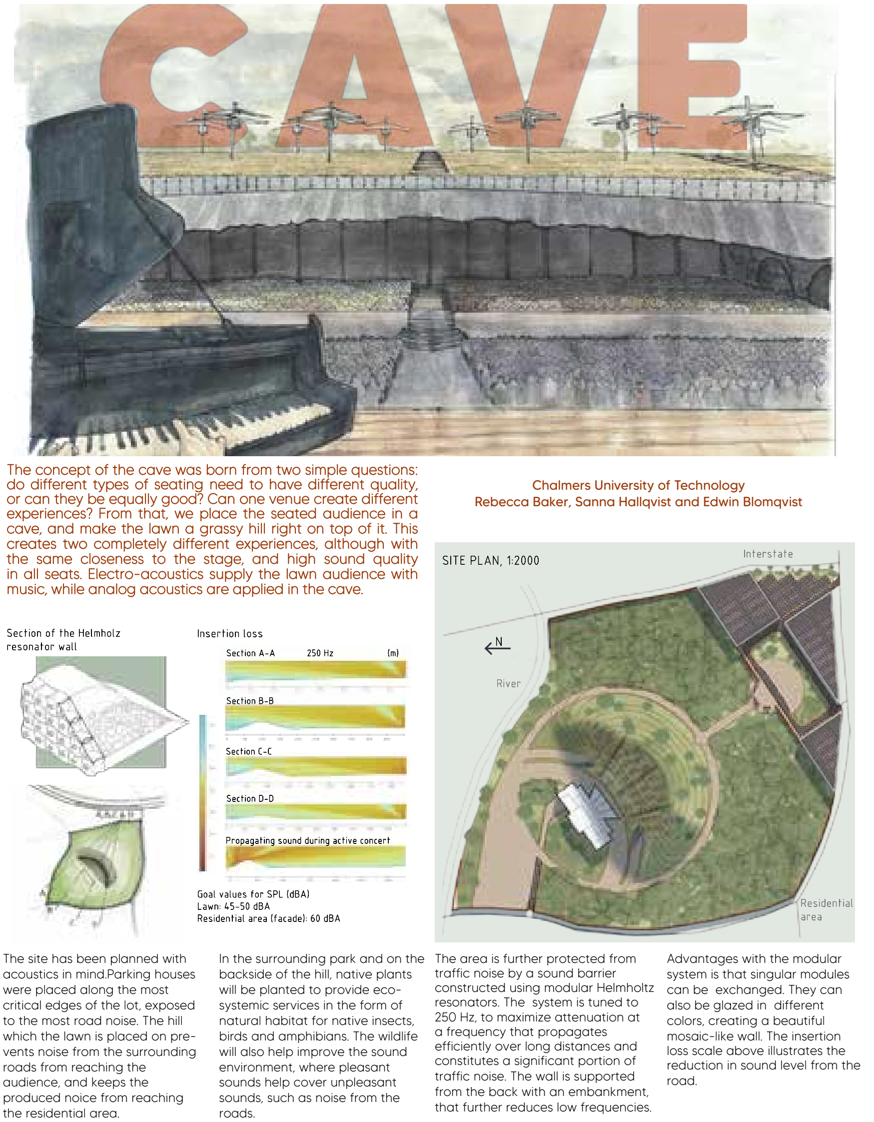
Technical Requirements
Design competition entries should emphasize the general building acoustics design (room acoustics, sound isolation, and noise control) and its interaction with the overall architectural design across all spaces. Emphasis should be placed on...

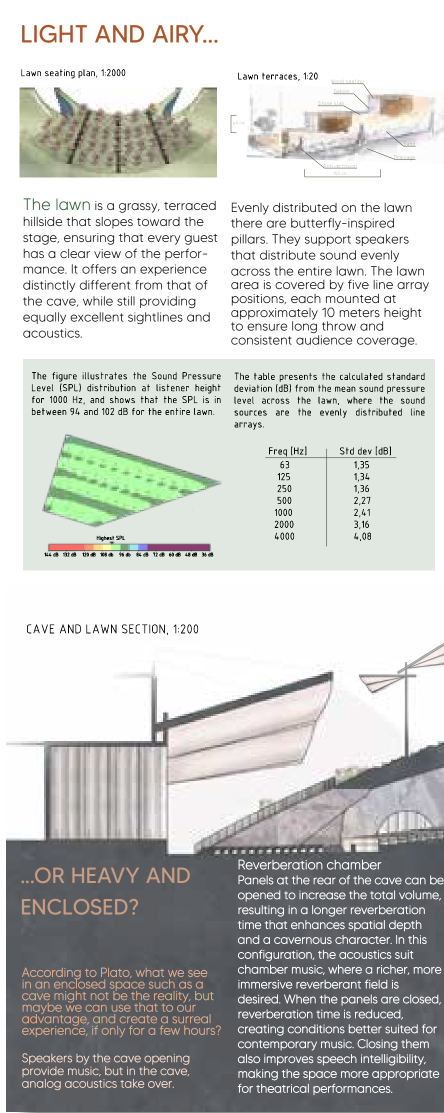
1. On-stage acoustic support for musicians hearing;
2. Ambient noise conditions on-stage from site noise (traffic and building equipment);
3. Impact of event sound and building equipment noise on nearby residential communities.

Drawings should present comprehensive solutions to the acoustic design in schematic design format. In addition to plans and sections, the poster boards may display acoustic calculations, acoustic criteria, and details of construction relating to acoustics and noise control as necessary to describe and support the design. If computer programs are used in the design, graphics and data from the programs may be displayed.

While the design of the building mechanical and electrical systems is very important to the acoustical success of a project, it is not necessary for this particular design problem to indicate in detail the mechanical and electrical system noise control procedures that are required. However, the presenter(s) may wish to indicate noise criteria, and general noise and vibration control procedures relating to air handling, electrical power transformers, theatrical lighting dimmers, etc. It is also not necessary for this particular design problem to indicate special stage equipment such as stage rigging, side and rear slip stages, traps, etc. As indicated above, the facility will require an electro-acoustic sound reinforcement system for distribution of sound to the main seating and the open lawn seating areas. It is not necessary to design this system as part of the overall design except to identify mounting locations at the stage and that open lawn coverage loudspeaker locations are to be provided and indicated.

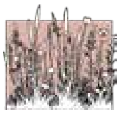
Finished competition presentation



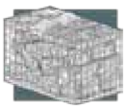


The set form of presentation for the competition was a limitation that made us compact our material into three posters, that came out a bit too crowded for our liking. But overall we are happy with the way we succeeded in communicationg our many ideas and solutions, as well as our acoustical analyses.

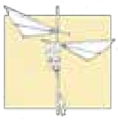
Each position consists of three cardioid line array loudspeakers. The cardioid design minimizes rearward radiation, improving clarity and maintaining a strong directional focus toward the stage.



Higher vegetation is placed behind the speakers where sightlines are impaired. In addition to improving biodiversity, the higher vegetation and soft ground absorbs some sound, combating reflections on the lawn.



In the terraces on the lawn, there are built in gabions that absorb sound, reducing reflections from behind the listeners and preserving a sense of direction.



The sails, or wings, of the butterflies help guide the sound while also providing a measure of shade for guests.

Rotating panels allow the space to be acoustically tuned by adjusting how far they are opened, enabling different acoustic properties depending on their position.

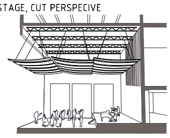
Diffusers in the cave
The irregularities of the walls and ceiling acts as diffusers for a fuller and enhanced sound quality, while architecturally imitating the inside of a natural cave. The soundwaves scatter and spreads evenly across the hall, creating a sense of spaciousness.

FLEXIBLE PERFORMANCE

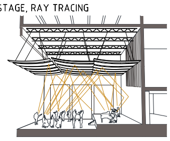
To ensure adequate communication for the musicians on the relatively large stage, the acoustic design prioritises the reflection of sound back to the performers. This is achieved through switching the standard cone shape for a rectangle, and the use of turnable reflective wall panels. These can reflect sound backwards but also open up into an extended stage, increasing the volume to enlongate the reverberation time. The back side of the panels can also be clad with sound absorbing materials, to shorten the reverberation time. In addition, the ceiling is designed to allow vertical adjustment depending on the intended use of the space and the orchestra.

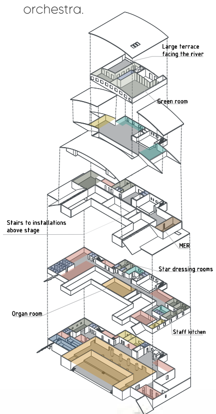
A pertruding roof combats glare and rain, protecting the musicians and their instruments. It also covers part of the seated audience, helps guide music towards the lawn and connects the volumes.

THE STAGE, CUT PERSPECIVE

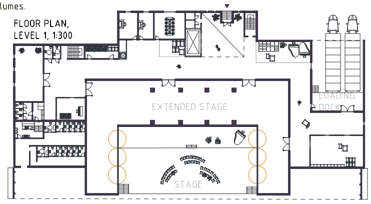


THE STAGE, RAY TRACING





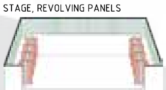
FLOOR PLAN, LEVEL 1, 1:300



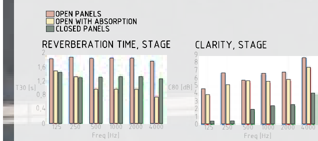
- Machinery, 81 m²
- NC-40 Guest restrooms
- NC-30 Storage, 640 m²
- NC-30 Dressing and locker rooms, 170 m²
- NC-30 BOH restrooms, 214 m²
- NC-25 Green room, 460 m²
- NC-25 Administration, 150 m²
- NC-25 Stage, 456 (+641) m²
- NC-20 Dressing and rehersal, 200 m²

Practice rooms are following the international standard for acoustic quality criteria for music rehearsal rooms and spaces. They are spread out through the building. Lockers for orchestra members are spread out between dressing rooms and rehearsal rooms. The loading dock and machinery are placed separately from acoustically sensitive areas. The entire building is raised to the height of the stage, so that heavy equipment does not need to be lifted. This is also a good fit for a raised loading dock.

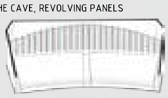
THE STAGE, REVOLVING PANELS



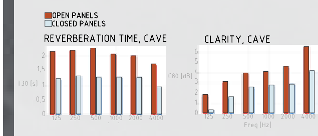
Red: open panels.
Blue: closed panels and curtains.



THE CAVE, REVOLVING PANELS

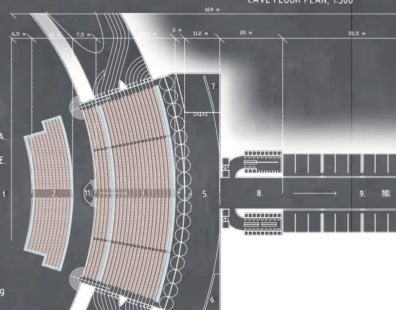


Red: open panels.
Blue: closed panels and curtains.



1. STAGE
2. ROOFED SEATING OUTDOORS, 968 SEATS. 1.1x0.5 m PER SEAT
3. SEATING INDOORS, 2064 SEATS. 1.2x0.6 m PER SEAT.
4. ENTRANCES
5. BACK OF AUDIENCE, MINGLE AREA.
6. BAR.
7. RESTAURANT, SEATS 121 PEOPLE.
8. RESTROOMS, 30 WC, 4 HWC, 9 URINALS.
9. CHECKROOMS, SPACE FOR 2880 BELONGINGS.
10. ENTRANCE, SLOPE 5%.
11. FRONT OF HOUSE.

CAVE FLOOR PLAN, 1:500



- Seating
- Wheelchair accessible seating

Creative Process

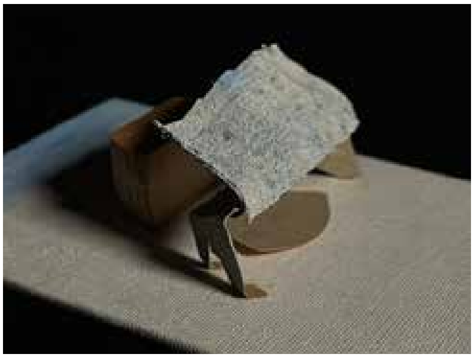
Assignment 1

In the first assignment of the bachelor project, the task was to create three distinct concepts. These concepts were to be communicated through three sections of the entire lenght of the 500 meter site in the scale 1:100, creating three five meter long sections. In all proposals we placed the stage close to the river in the north, and so we decided to paint the proposals on top of each other to display their differences and similarities.

Our first concept was called "the wing", and utilizes a seated area with a large balcony overhead. The lawhn audience views the performance through the structure upholding the balcony.

Our second concept. "the beak", has roofed seating to the right facing the stage, and lawn seating to the left. This allows the lawn audience to come close to the stage. Back of house areas are utized as an acoustic wall on the right side of the seated audience.

Our last concept, "the egg", is what will later be developed into the cave. This early concept is never compromized, but only evolves as problems are discovered.

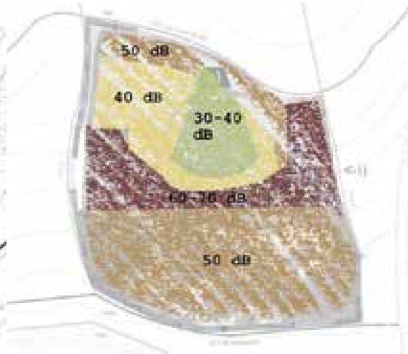





Assignment 1

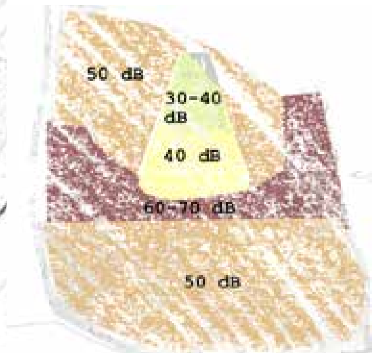
the wing

goal spl



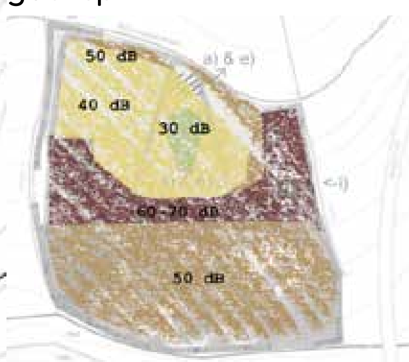
the beak

goal spl



the egg

goal spl



a) Stage & BOH

b) Roofed seating and balcony seating

c) Lawn seating

d) Major walkways

e) Lawn/Park

f) Market area/ toilets/ square

g) Parking

h) Forest/park with art-/ sound instillations

i) Acoustic barrier/wall

For the wing we imagined using double acoustical walls and terraforming to create a large silent area, disconnected from the sounds of the city.

For the beak, we use the back of house area as a long wall, creating a long silent area. We didn´t have as much need for a wide lawn space suitable for music, so we let the west side of the lawn be a bit more noisy.

For the egg, we planned to let the back and sides of the hill be a bit more noisy and connected to the city life, while the part of the lawn closest to the stage would be a true musical experience, disconnected from the surrounds.

For all concepts, the stage is placed close to the river to the north. This creates a large distance between the stage/audience, and the road to the south. The position also creates nice areas to dwell by the water, and gives freedom in placing entrances.Later in the project, we come to realize that the road to the east is more critical, which makes us rething our site plan. All concepts include an "art park", where local artists can contribute installations, preferrably surrounding music and the sounds of nature. The concepts also include a market area, where food trucks and other supporting businesses can be placed during larger events.

Assignment one was presented for the students of the Acoustical Engineering masters programme on Chalmers, and we were paired up with students Albin Wessman and Edwin Blomqvist. Our collaboration started of by finding out which parts of our initial work interested them the most, and together we decided which of the three concepts we would like to explore further.

We decided to continue our work with "the egg" which in itself was a strong concept that we in many ways kept throughout the project. As problems were identified, they were solved and the concept itself was refined. In the early parts of our collaboration we also formed an understanding of what a collaboration between architecture and acoustics looks like, communicating our strengths and limitations. Early on, we realized that the geometry of the cave was an opportunity to apply room acoustics rather than electroacoustics, which changes the task which was set for the acousticians.

The concept interested the architects through the possibility of creating wildly different experiences for the same event, as well as an interesting meeting between them. The lawn crowd is directly above the seated audience, but are they even aware of each other? The same concept interested the acousticians by providing an opportunity to further work with analog acoustics in a challenging setting.

We later find opportunities to integrate some aspects from the other two concepts in our final proposal, for examples the sails of the wing which end up playing a crucial part in acoustical environment of the lawn. A large sail similar to the one on the wing also helps connect the stage to the lawn, helps protecting the stage and covers some seated audience.

The concept of the art park is kept in the final project, although with less focus. This park area provides the opportunity to create a biodiverse environment, which in turn elevates the soundscape in the area.

Creative Process
Assignment 2

clay model of the lawn and cave

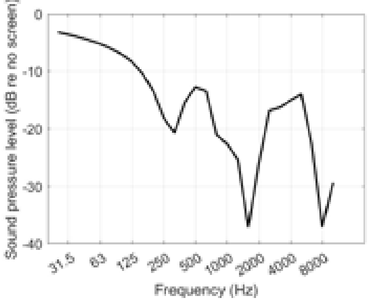
For assignment two, the task was to create acoustical models of the different parts - the stage, the seated area and the lawn. This process was a way of visualizing how sound moves, which materials it meets and where and how it reflects. The models were also where we first started forming an understanding of where speakers will need to be placed, and how speaker towers could be designed to fit the ambience of the lawn.

At this point, we realized the size of the cave necessary to fit such a large audience, and the extensive care needed to make it accessible and open. We then added openings on all sides to be used as paths, as well as a possibility to change the acoustics inside.

The second clay model was created by cutting the top of the first one, displaying the inside of the cave. At this point, we realized the length of the cave was an issue, since a room length over 50 meters can create unwanted echoes. We split the volume with a wall, giving us the possibility to integrate facilities such as bathrooms, bars and warder-obes inside the hill. We also had the idea to make the wall possible to open up, which results in a different reverberation time. We can also use different materials to our advantage.

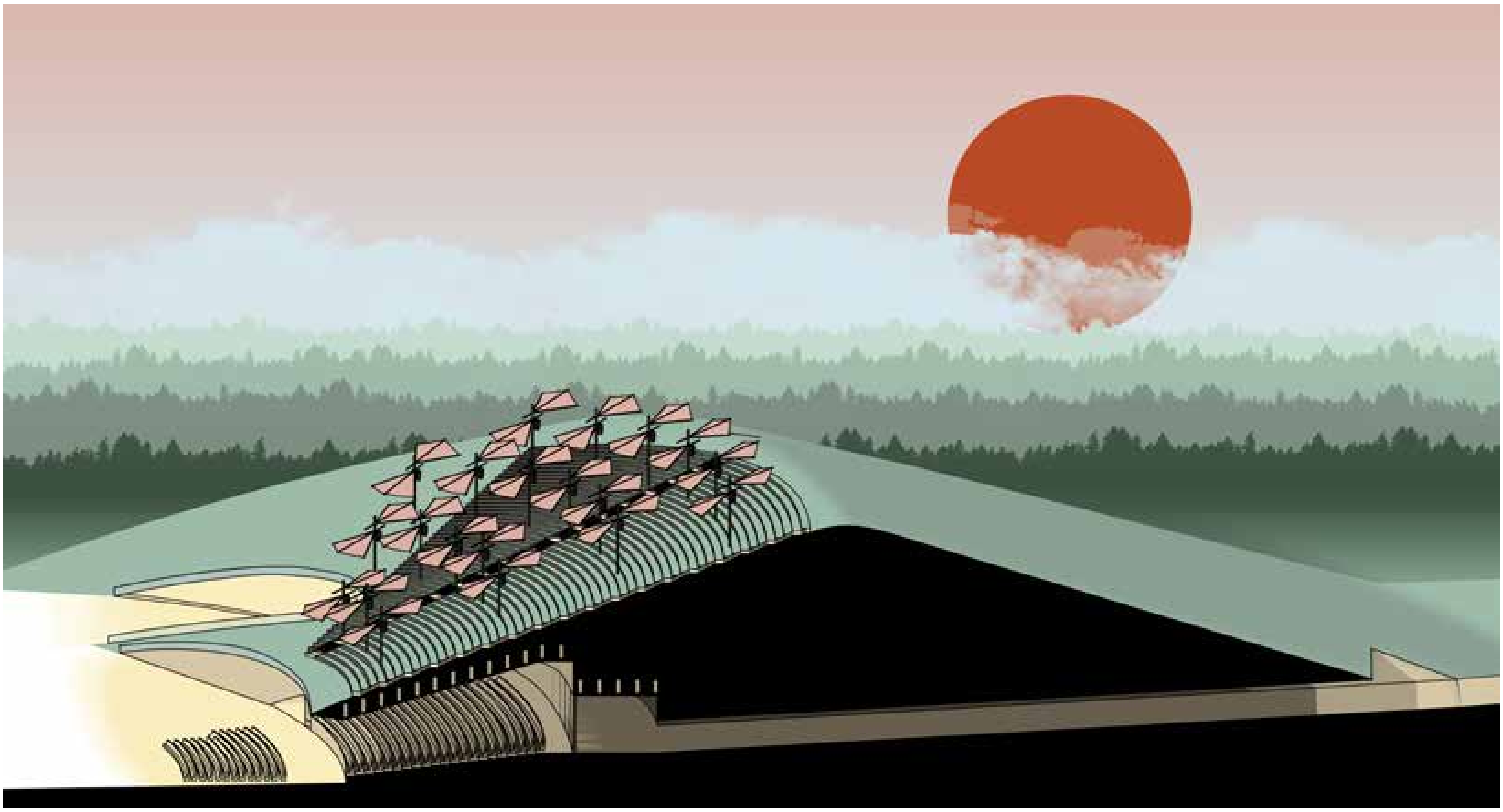
After making the models, photographs of them were taken into Photoshop to add people and vegetation, to see if we achieve our desired ambience. We knew we wanted to integrate lots of greenery, since soft soil and high vegetation helps absorb sound. We decided early on that this would be an addition to the ambience, and we welcomed the feeling of a grassy fairytale-like hill, with co-workers and teachers making connections to Moomin, Teletubbies and Hobbit houses.

From early on, we had picked up that the perfect stage for this venue had a great focus on first reflections. That made us design a rectangular stage, rather than the standard cone shape of a stage for an analog venue. This also led to adjustable panels in the ceiling, that can be lowered to help with first reflections for a smaller orchestra.


Sound pressure level (dB re no screen)
0
-10
-20
-30
-40
31.5
63
125
250
500
1000
2000
4000
8000
Frequency (Hz)

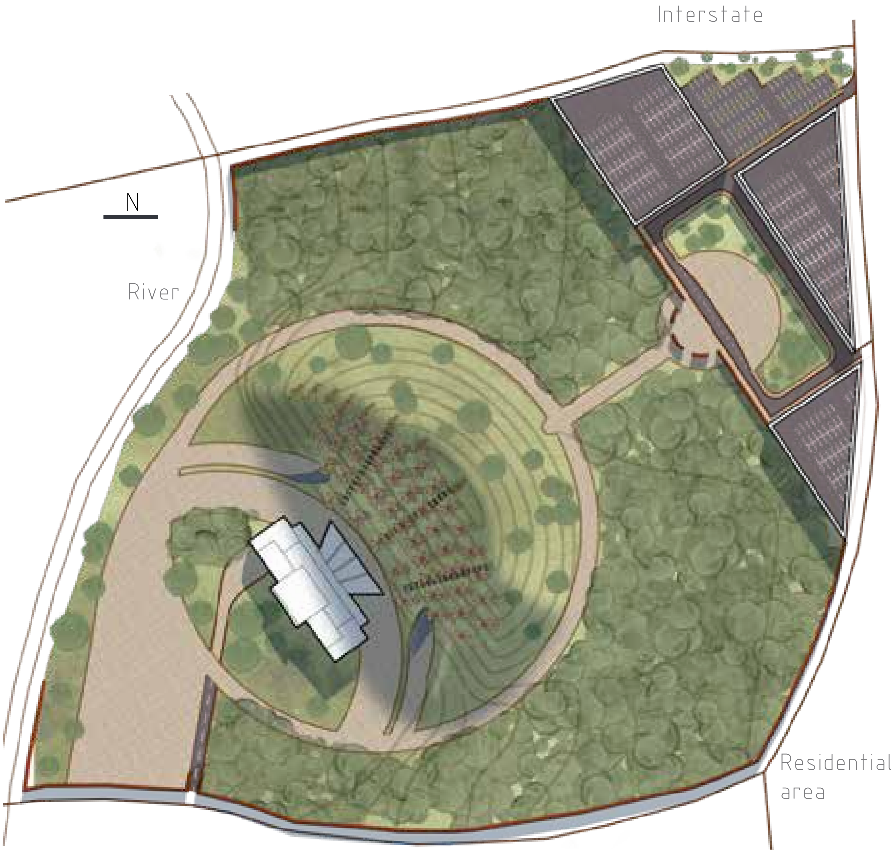
The first acoustic solution we found before meeting our acoustic counterparts were the Helmholtz bricks designed by Joe Makes for his architecture thesis. These are resonators that can be stacked and mass produced using slipforms. In addition, they can also be glazed creating a simple and aesthetic acoustic element. We decided we wanted to utilize it as a part of the colourful identity of the project as an absorber for the highway and interstate. This later became the protective wall that follows the entire circumference creating curious and representative visual introductions along the surrounding roads. This later proved to be necessary as the geometry of the wall and distance from the interstate made certain frequencies hard to block and even amplified some. Using the Helmholtz resonator these frequencies could be targeted and effectively absorbed.

finished project



Transforming the early ideas to a finished project came quite easily, since we had so many ideas from just the first weeks of the project. We had loads of solutions for acoustics, construction, infrastructure and effectivity, as well as an understanding of the general feeling we wanted to accomplish. The early stages of the cave naturally transformed into something emotional, functional and more realistic than we thought our "out there" concept could ever be.

the site

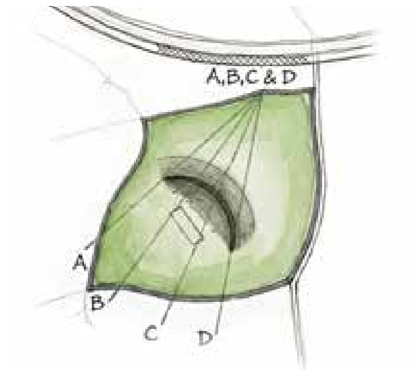


The site plan has evolved over time, but its main elements remain: the hill, entrance, marketplace, and art park. The entrance is now placed in the northwest corner, with accessible ground-level parking, parking structures, and bus stops. A green plaza framed by parking buildings is oriented toward the cave entrance, clearly guiding visitors toward the hill. From here, visitors can enter through five access points, two on the sides and three in the center, connected to the main walkway. Beyond this lies the art park, with wild forest, sculptures, and winding paths leading to the hill in the south-central area, where visitors can enter into the cave, walk around or climb to the top.

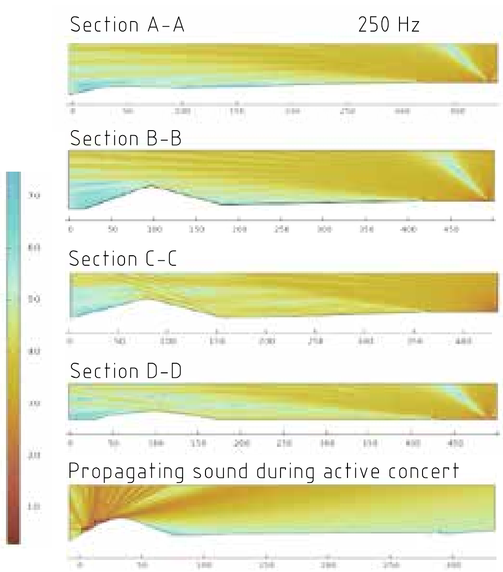
Past the hill, more open space reveals structures such as speaker towers and back-of-house facilities, creating contrast with the surrounding forest and cave but still introducing variation. While many visits end here, larger events extend to a waterfront marketplace with space for temporary structures, toilets, food trucks, and seating. This area also includes a separate service entrance for deliveries, with access to back-of-house functions and a turning area designed for large vehicles and equipment.

The entire area remains accessible outside of paid events, functioning as an open art park for nearby communities. The surrounding walls help reduce noise pollution and allow entrances to be controlled when needed for security or ticketed events.

site



Insertion loss



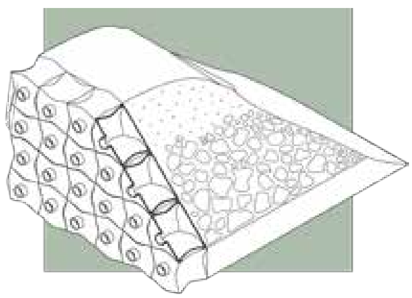
Goal values for SPL (dBA)
Lawn: 45-50 dBA
Residential area (facade): 60 dBA

The site has been planned with acoustics in mind. Parking houses were placed along the most critical edges of the lot, exposed to the most road noise. The hill which the lawn is placed on prevents noise from the surrounding roads from reaching the audience, and keeps the produced noice from reaching the residential area.

The area is further protected from traffic noise by a sound barrier constructed using modular Helmholtz resonators. The system is tuned to 250 Hz, to maximize attenuation at a frequency that propagates efficiently over long distances and constitutes a significant portion of traffic noise. The wall is supported from the back with an embankment, that further reduces low frequencies.

Advantages with the modular system is that singular modules can be exchanged. They can also be glazed in different colors, creating a beautiful mosaic-like wall. The insertion loss scale above illustrates the reduction in sound level from the road.

Section of the Helmholz resonator wall



biodiversity

In the competition submission, the format did not give us enough space to emphasise much sustainability, although we had many thoughts regarding how to make such a large and heavy building sustainable and ethical. See pages 46-47. We still wanted to include some way of empathizing sustainability, and we therefore chose to put some focus on biodiversity while this can also be of acoustical advantage.

The site is large, and would lead to excess space no matter which concept we choose to go through with. Rather than make it into a structured park, our ambition was to keep it as natural as possible, and even adding more native plant species which would then attract animals and insects.

There is a natural body of water, the river, adjacent to the site that when left alone can hopefully attract amphibians and water-living birds. We have also looked into construction a pond in the south-west corner of the site for the same reasons.

There are large areas along the south, east and west borders of the site that are not needed for structures or communication, where native plants can be planted in tiers of trees, bushes and ground covering plants that are native to the area and attract insects and herbivores. The insects then attract birds that can nest in the treetops.

A site that boils with living creatures, chirping, croaking and singing, wind blowing through treetops and rusteling grass creates a soothing soundscape. It is clinically proven that being in nature is one of the greatest remedies for human stress. We imagine that walking through this natural park on your way to the performance would put the audience in the right state of mind for a calming outdoor performance, while creating a large mental distance to the outside world. The natural sounds help cancel out noise from the interstate, since 50 dB of road noise is far more aggrevating than 50 dB of bird song.

High vegetation requires soft soil, which in combination helps absorb low frequencies. Having this typ of ground in large parts of the site will stop some sound from escaping and reaching the events. We are also planning on incorporationg some patches of higher vegetation on the lawn, in spots where sightlines are impaired or speakers are too close for comfort. This brings some biodiversity close to the audience, and makes the spot more connected to nature. On the hill you would be among the treetops, sitting in between patches of wildflowers, viewing the river and listening to the bird song, while enjoying classical music with friends and family.

The site is based in north america, so bio-diversity would be achieved through plants such as:

Oak trees: Supports over 500 species of caterpillar, supplying bird food.
Willows: Produces nectar early in the season to provide bees and other pollinators.
Black cherry: Supports massive biodiversity through trunk, flowers and berries.
Serviceberry: Provides birds with berries.

Milk weed: Essential for Monarch butterfly breeding.
Goldenrod: A powerhouse for bees, wasps and butterflies.
Coneflower: Attracts bees and supplies birds with seeds.
Asters: Crucial late-season nectar and pollen source.
Sunflowers: High seed-production for birds.

Switchgrass: Great for erosion-control and nesting habitat.
Broom sedge: Provides winter coverage for wildlife.
Bearberry: Evergreen ground coverage, that sustain animals even in winter.

the lawn

SITE PLAN,

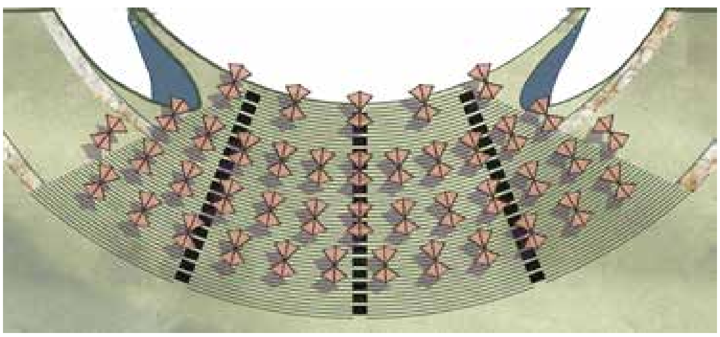
The lawn is a grassy, terraced hillside that slopes toward the stage, ensuring that every guest has a clear view of the performance. It offers an experience distinctly different from that of the cave, while still providing equally excellent sightlines and acoustics.

The lawn will be placed above the with seating stretching 0-30 meters outside of the cave structure and 35 meters behind. The structure will utilise dirt that is excavated during construction and landscaping. This will be used in addition to other materials transported to the site or refurbished (see the section about sustainability).

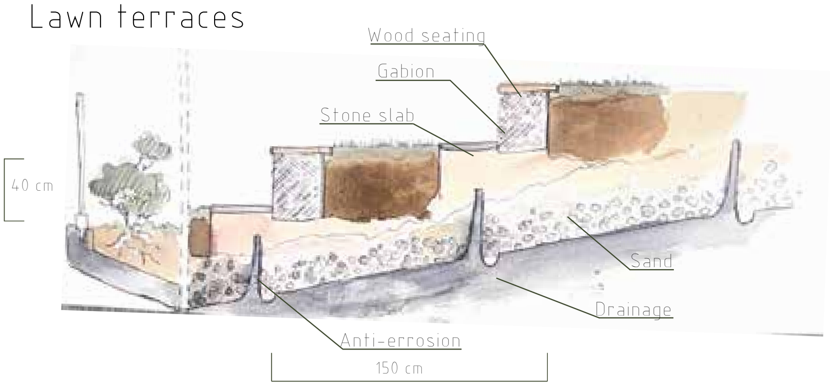
To prevent erosion concrete ridges clad in water resistant materials are extended from the vault roof, this also helps lead water and moisture away from the structure and cave opening. Above, gabions create terraces that combat the same erosion problems whilst simultaneously absorbing sound from speakers.

Between these layers we will place sand to absorb vibrations from the crowd. In addition neither gabions nor stairs on the lawn will be connected to the cave structure combating vibrations spreading that way.

Lawn seating plan



Lawn terraces

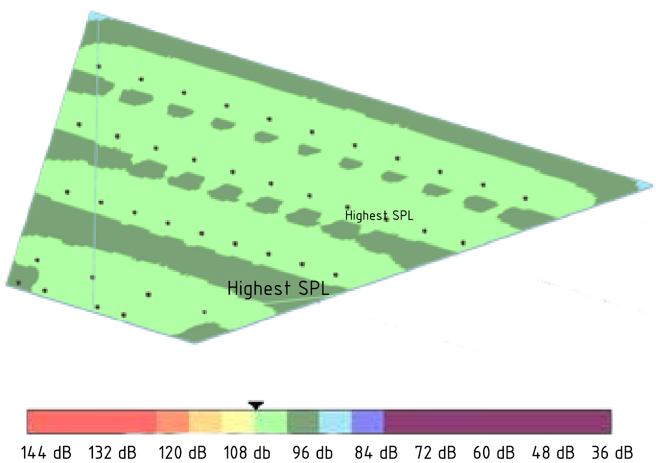


lawn

Evenly distributed on the lawn there are butterfly-inspired pillars. They support speakers that distribute sound evenly across the entire lawn. The lawn area is covered by five line array positions, each mounted at approximately 10 meters height to ensure long throw and consistent audience coverage.

Each position consists of three cardioid line array loudspeakers. The cardioid design minimizes rearward radiation, improving clarity and maintaining a strong directional focus toward the stage.

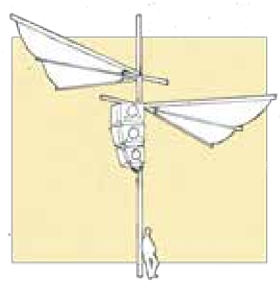
The figure illustrates the Sound Pressure Level (SPL) distribution at listener height for 1000 Hz, and shows that the SPL is in between 94 and 102 dB for the entire lawn.



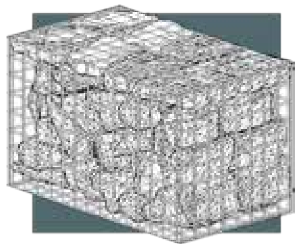
The table presents the calculated standard deviation (dB) from the mean sound pressure level across the lawn, where the sound sources are the evenly distributed line arrays.

Freq [Hz]	Std dev [dB]
63	1,35
125	1,34
250	1,36
500	2,27
1000	2,41
2000	3,16
4000	4,08

Higher vegetation is placed behind the speakers where sightilines are impaired. In addition to improving biodiversity, the higher vegetation and soft ground absorbs some sound, combating reflections on the lawn.

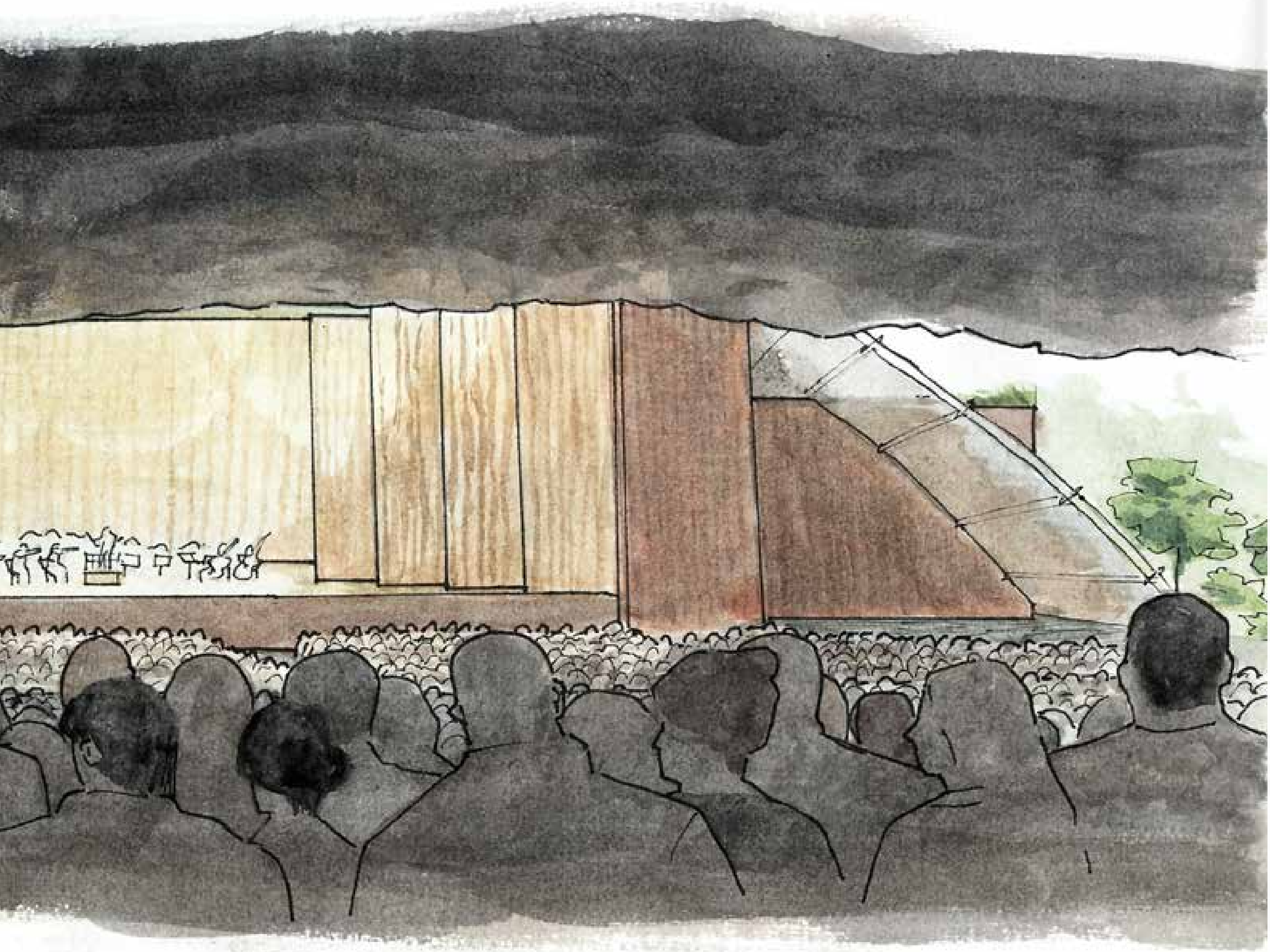


The sails, or wings, of the butterflies help guide the sound while also providing a measure of shade for guests.



In the terraces on the lawn, there are built in gabions that absorb sound, reducing reflections from behind the listeners and preserving a sense of direction.

the cave

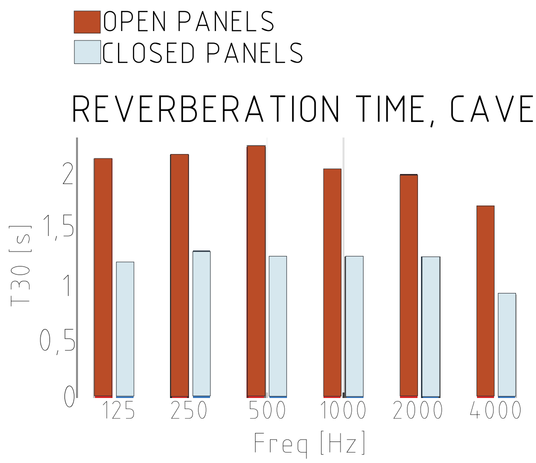


The main part of the seated audience is placed inside of the cave, with some seated in the space between the stage and the cave. The seats under the sail roof are covered by a per-truding sail roof, and the seats are detachable to allow the space to be transformed into standing-room for larger concerts. When the orchestra plays, these seats are our main ac-cessible seats. The cave has a main entrance through a tunnel from the back. When entering through here, you pass by bathrooms, warderobes, a bar and a restaurant before reaching your seat. These areas can be covered in art and mosaics, to make the space more interest-ing and to reference the colourful Helmholz wall around the site. The cave also has entrances to the sides and the front, to keep some connection to the outdoors and for safety reasons. There are rotatable panels between the seats and back of audience area. When open, the panels resemble pillars and makes the space more approachable. Opening an closing the panels change the reverberation time in the room, to accomodate different events.

According to Plato, what we see in an enclosed space such as a cave might not be the reality, but maybe we can use that to our advantage, and create a surreal experience, if only for a few hours?

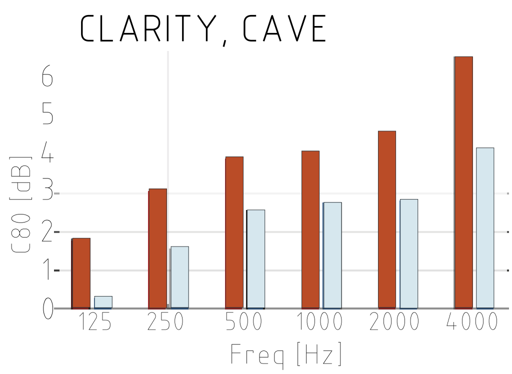
Reverberation chamber

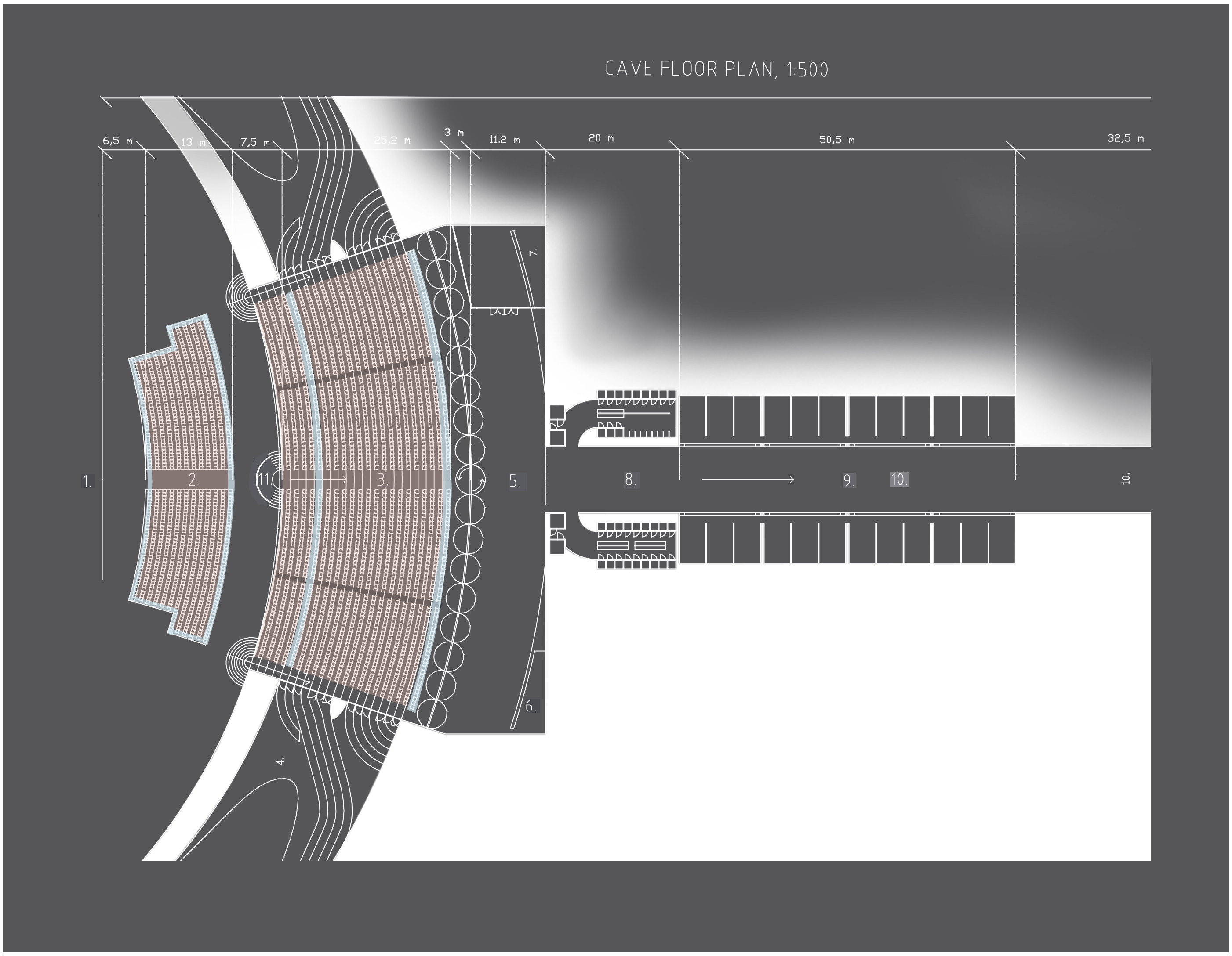
Panels at the rear of the cave can be opened to increase the total volume,
resulting in a longer reverberation time that en-hances spatial depth and a cavernous character. In this configuration, the acoustics suit chamber music, where a richer, more immersive reverber-ant field is desired. When the panels are closed, reverberation time is reduced, creating conditions better suited for contemporary music. Closing them also improves speech intelligibility, making the space more appropriate for theatrical per-formances. Rotating panels allow the space to be acoustically tuned by adjusting how far they are opened, enabling different acoustic properties depending on their position.



Diffusers in the cave

The irregularities of the walls and ceiling acts as diffusers for a fuller and enhanced sound quality, while architecturally imitating the inside of a nat-ural cave. The soundwaves scatter and spreads evenly across the hall, creating a sense of spaciousness.



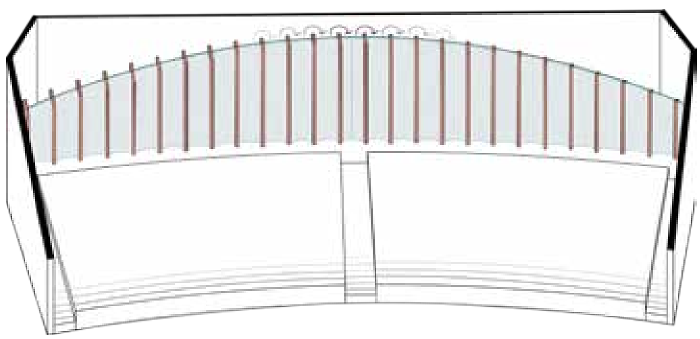


1. STAGE
2. ROOFED SEATING OUTDOORS, 968 SEATS. 1.1x0.5 m PER SEAT
3. SEATING INDOORS, 2064 SEATS. 1.2x0.6 m PER SEAT.
4. ENTRANCES
5. BACK OF AUDIENCE, MINGLE AREA.
6. BAR.
7. RESTAURANT, SEATS 121 PEOPLE.
8. RESTROOMS, 30 WC, 4 HWC, 9 URINALS.
9. CHECKROOMS, SPACE FOR 2880 BELONGINGS.
10. ENTRANCE, SLOPE 5%.
11. FRONT OF HOUSE.

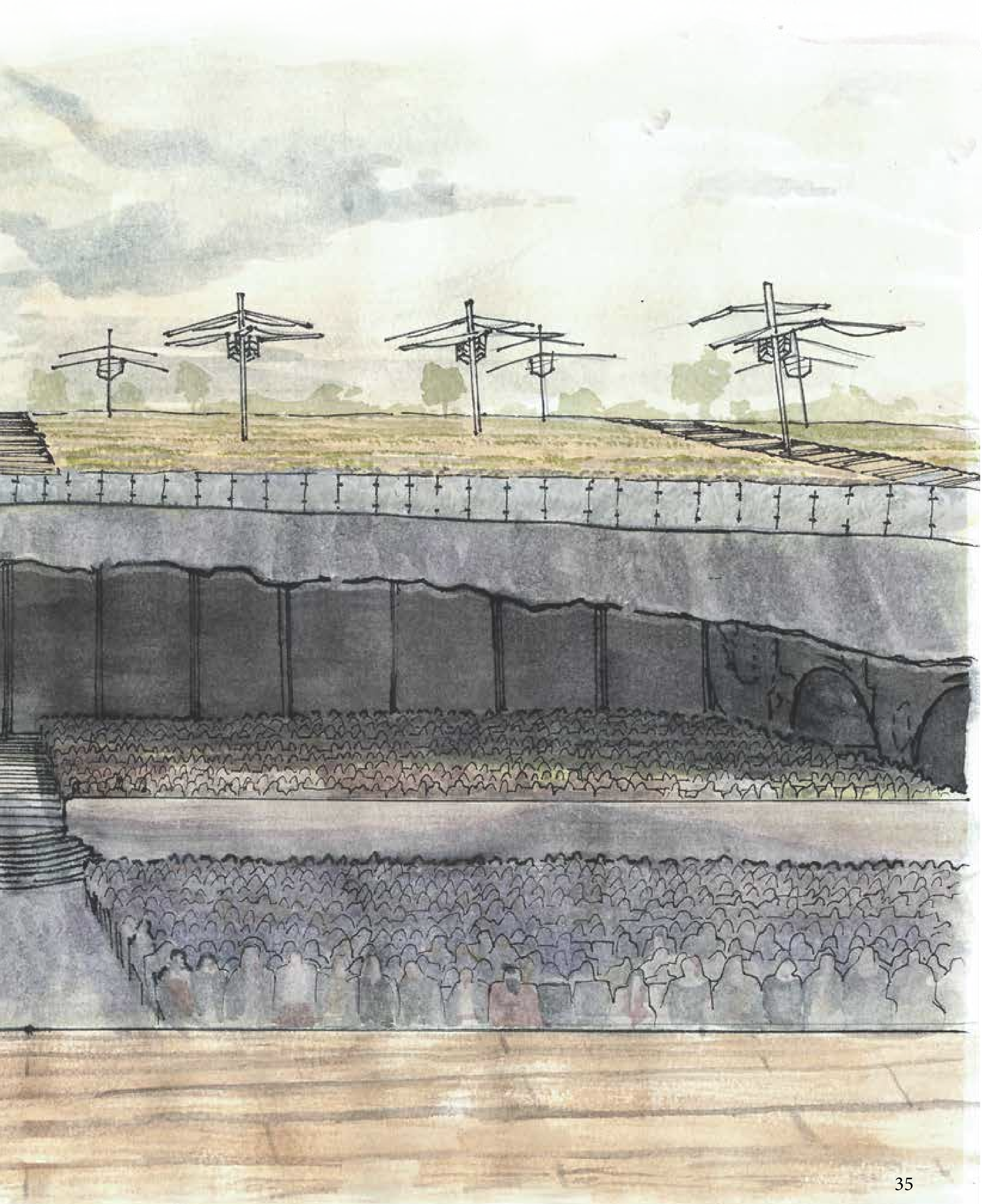
Seating

Wheelchair accessible seating

THE CAVE, REVOLVING PANELS



Red: open panels.
Blue: closed panels and curtains.

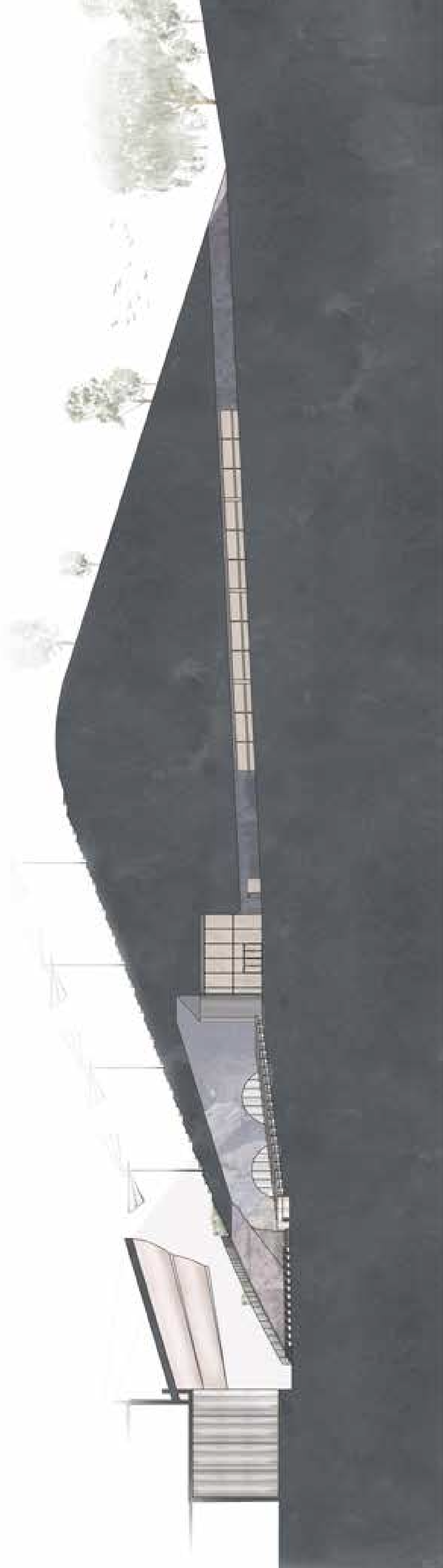


construction

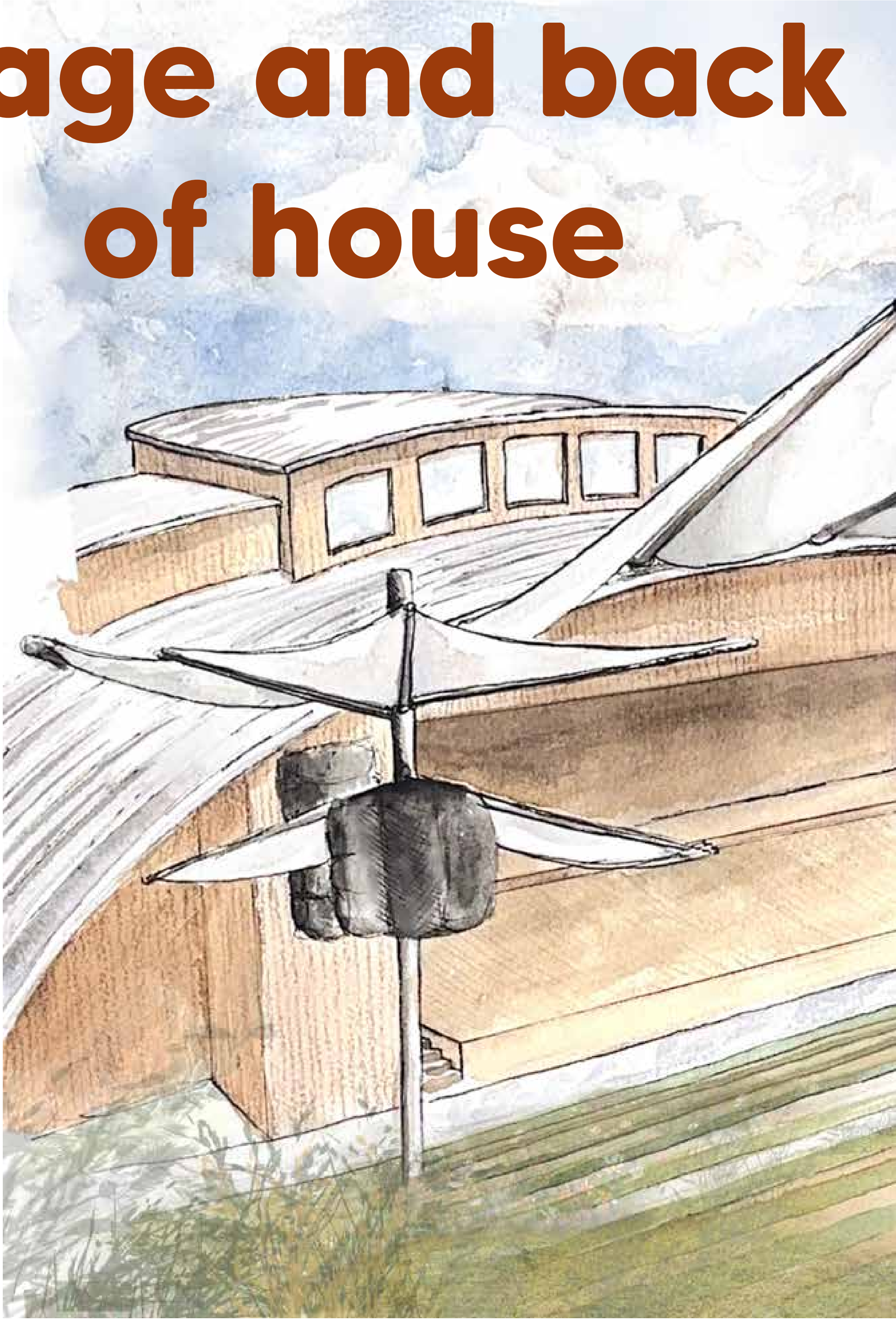
The construction of the cave was a result of negotiations between acoustics, sightlines and aesthetics. In the end we decided to use poststressed concrete vaults to bear the weight of the lawn audience and terraces. The plan was to overdimension the concrete vaults to guarantee stability and possibly downsize them later. The vaults are additionally supported at the edge of the cave and end circa 25 m outside the cave walls. They were dimensioned to stand 2.7 meters above the stairs along the edges and meet at 5 meters above the public at its lowest to allow visibility as well as accessibility.

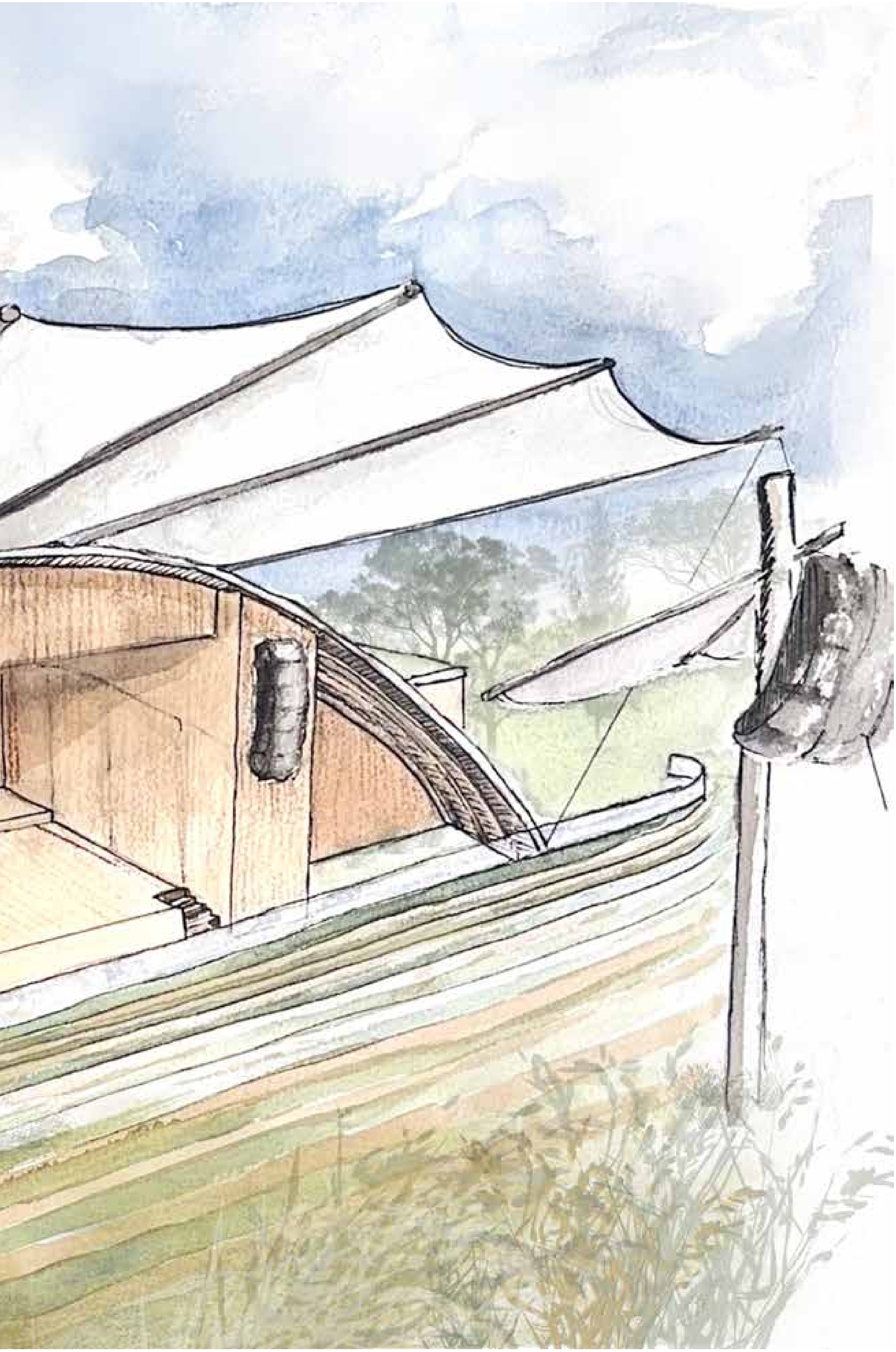
Further back the cave widens which also pushes the wall supports further apart. However the distance between the cave roof and the lawn increases dramatically at the same time. This allows for forces to be led sideways through the ground landing more broadly on the structure, decreasing stress.

The sideways openings are also intentionally designed to be in the shape of a half circle and separated into two by the cave wall to properly lead forces into the ground and support the end of vaults that cant stretch further outwards.
Beyond the primary construction the plan was to utilise cast concrete in combination with rebars to create a cave like surface for the roof and walls whilst using smooth stone or prefabricated concrete for the flooring. This however can be interchanged with a more economically reasonable and sustainable solution discussed in the section about sustainability.



stage and back of house



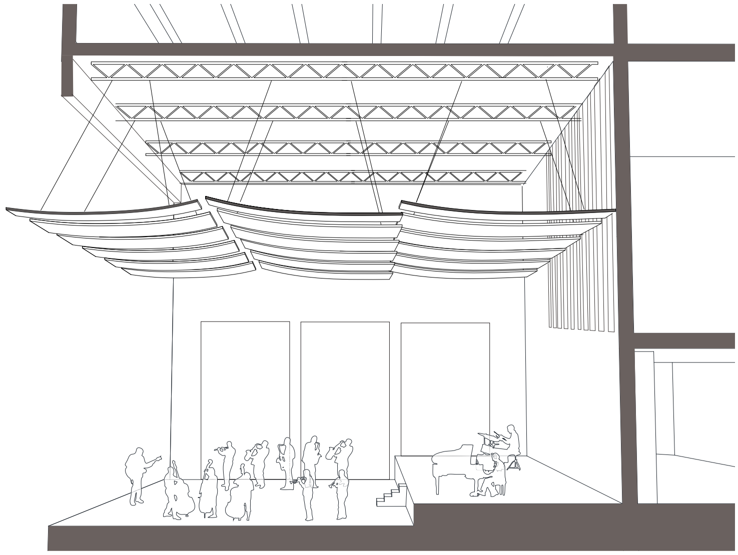


FLEXIBLE PERFORMANCE

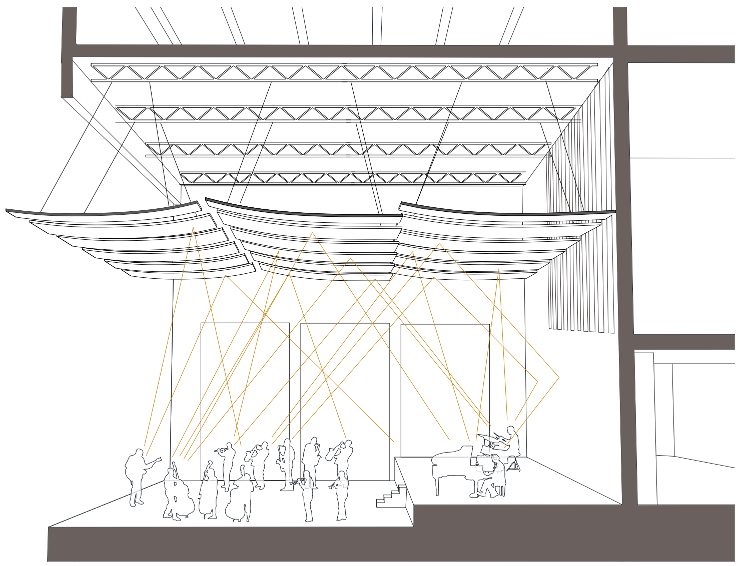
To ensure adequate communication for the musicians on the relatively large stage, the acoustic design prioritises the reflection of sound back to the performers. This is achieved through switching the standard cone shape for a rectangle, and the use of turnable reflective wall panels. These can reflect sound backwards but also open up into an extended stage, increasing the volume to enlongate the reverberation time. The back side of the panels can also be clad with sound absorbing materials, to shorten the reverberation time. In addition, the ceiling is designed to allow vertical adjustment depending on the intended use of the space and the orchestra.

On the second floor, behind the stage, there is room for a large organ. When used, panels open up to the stage. Above the stage, there are structures for installations such as lights and hanging microphones. Above that, there is room for maintainance of this technology.

THE STAGE, CUT PERSPECIVE



THE STAGE, RAY TRACING



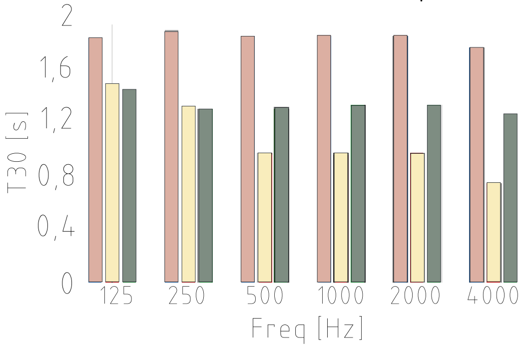
THE STAGE, REVOLVING PANELS

Red: open panels.
Blue: closed panels
and curtains.

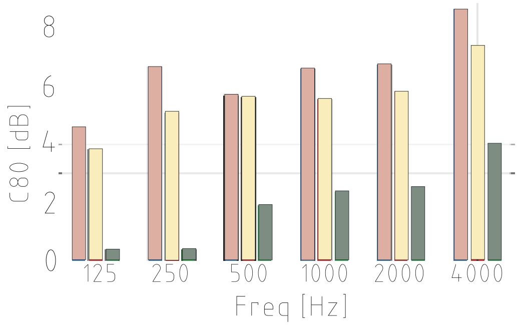
The sides of the stage open up onto an extended stage. This area has reflective walls, which can be covered in curtains and absorbing panels to change the reverberation time. The area an also be used for performances that need extra support in the form of smoke, back stage touch-ups, extra sound equipment, quick instrument changes and much more, making the area suitable for big performances.

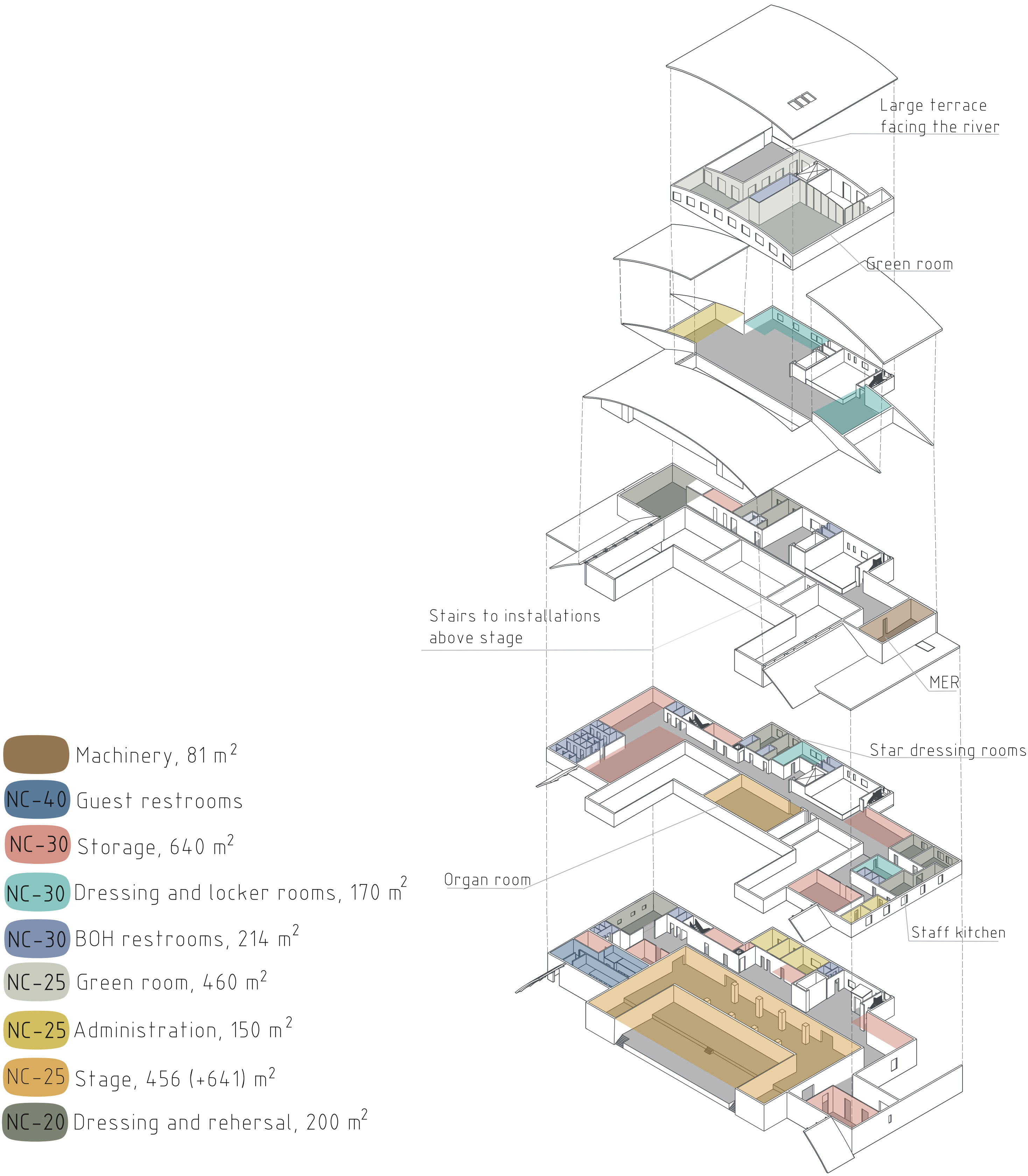
OPEN PANELS
OPEN WITH ABSORPTION
CLOSED PANELS

REVERBERATION TIME, STAGE

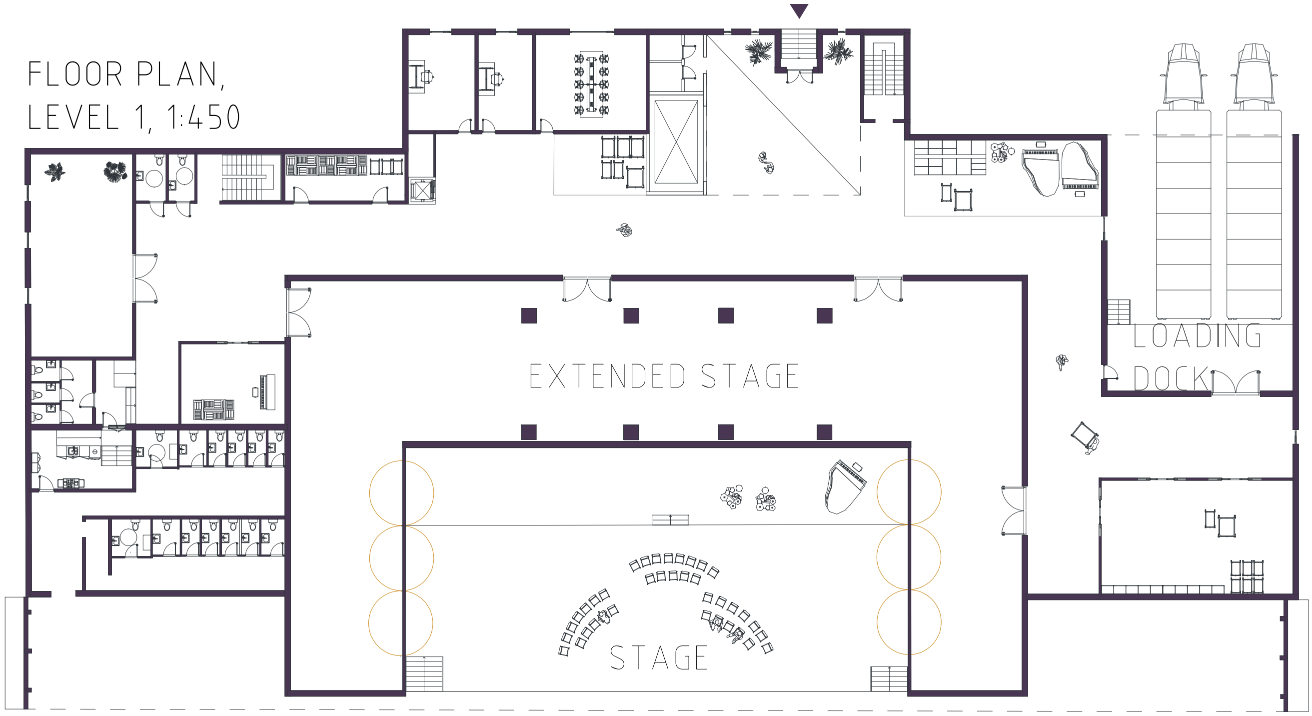


CLARITY, STAGE





Large terrace
facing the river
Green room
Stairs to installations
above stage
MER
Star dressing rooms
Organ room
Staff kitchen
Machinery, 81 m²
NC-40 Guest restrooms
NC-30 Storage, 640 m²
NC-30 Dressing and locker rooms, 170 m²
NC-30 BOH restrooms, 214 m²
NC-25 Green room, 460 m²
NC-25 Administration, 150 m²
NC-25 Stage, 456 (+641) m²
NC-20 Dressing and rehersal, 200 m²



The first floor is raised to the height of the stage (1,6-1,8 meters). This makes sure that no heavy equipment has to be lifted when transported to and from the stage. We have also raised the infrastructure on the back of the building a bit, to create a good fit for a loading dock with a height of 1,3 meters, which fits two large trucks. This loading area is covered, to allow safe handling of the sensitive instruments.

The building has a central shute, that opens up and connects all five floors for an airy and luxurious workspace. We also fit in some guest bathrooms, performer bathrooms close to the stage and larges areas for storage and instrument care.

Practice rooms are following the international standard for acoustic quality criteria for music rehearsal rooms and spaces. They are spread out through the building. Lockers for orchestra members are spread out between dressing rooms and rehearsal rooms on all floors, where we imagine the performances could be split up between instruments. There are many restrooms and dressing rooms with showers and vanities, making sure all performance have comfortable spaces to get ready.

There is a small kitchen and lounge area on the second floor, as well as extra offices and conference areas.

Machine equipment rooms and rehearsal rooms are placed with distance to each other and the stage, to ensure noise criterias are met.

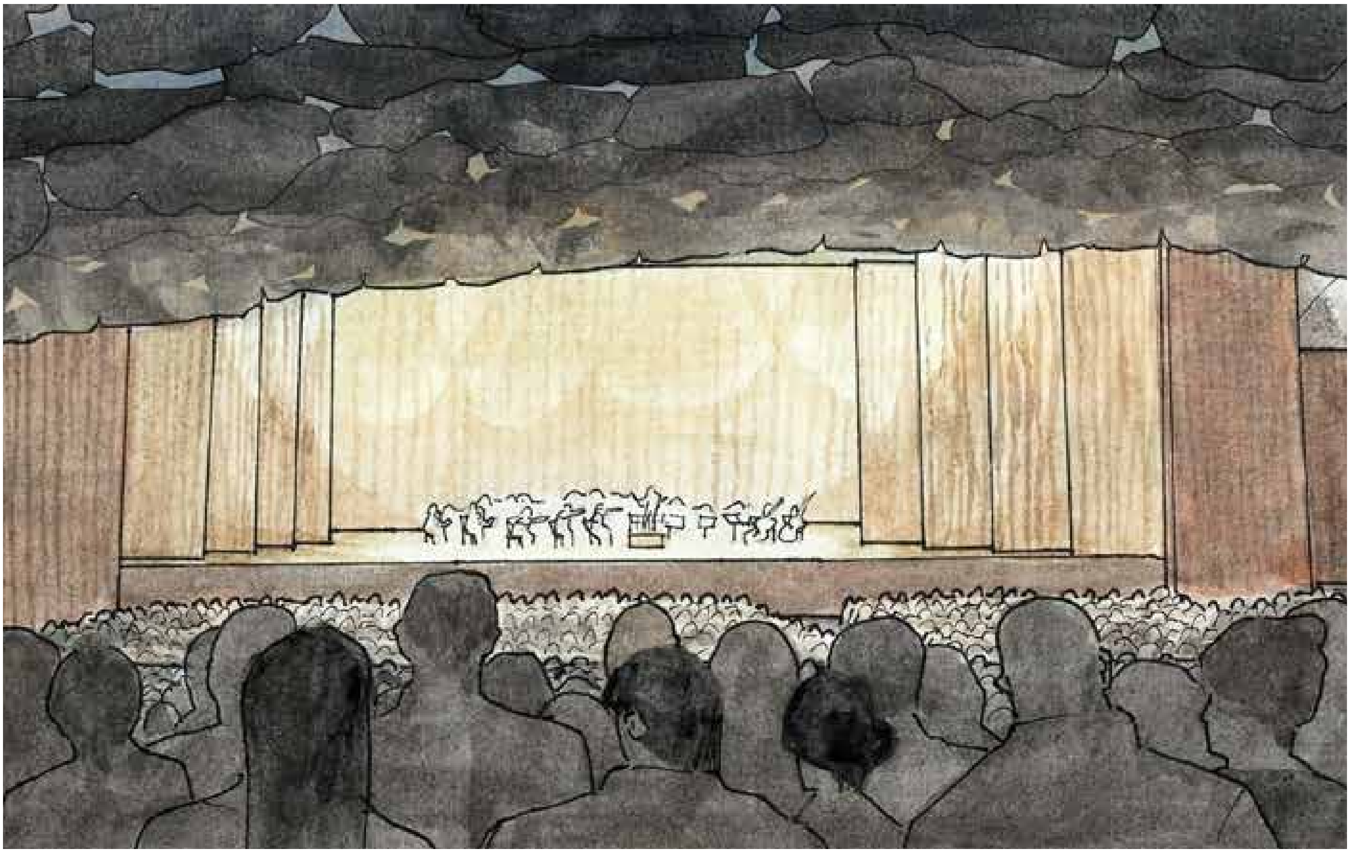
flexible atmosphere

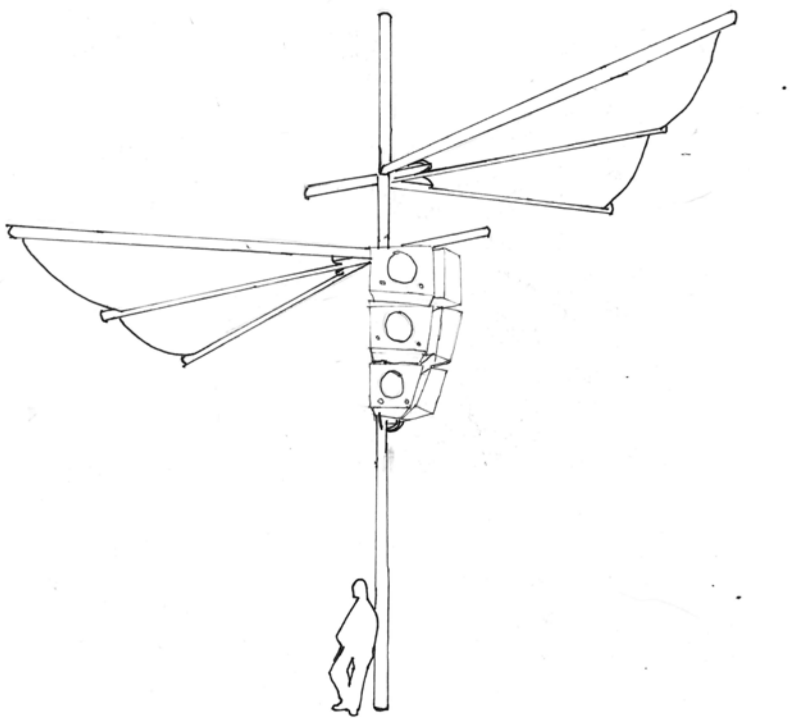
The roof pertruding from the stage covers some seated audience, protects the stage from glare and harsh weather conditions, helps guide the sound, blocks noise leakage and connects the two volumes, the stage building and the hill. It is made from a thick weather-proof textile, and wax coated to reach the desired acoustical qualities.

The sails on the speaker towers are made from the same material, and they help guide the sound while also providing a measure of shade for visitors.

Further, both of these structures can be used to create a custom ambiance for certain performances, when we place lights to illuminate the sails from underneath.

We imagine colored LED-spot lights, that can be controlled from the front-of house area and change with the performance. This brings the on-stage performance to every visitor. Inside the cave, lights are embedded in the irregular surface of the ceiling and walls, as well as in the floor along the paths. There is also room for spotlights along the floor by the walls, which can create a similar experience to the coloured sails on the lawn. The lighting would also amplify the texture of the cave, making this under-ground, other-worldly experience even stronger.





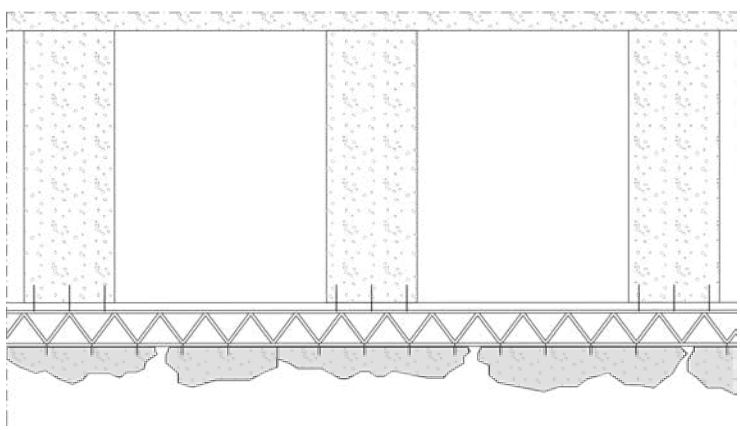
sustainability

The project relies on large-scale proportions and a layered system, with the lawn audience positioned above the cave audience. This arrangement is constrained by sightlines and structural demands; we couldn't add pillars in the cave without creating seats with blocked views, and the lawn required a steep slope for clear visibility. These factors led to a compact design where post-tensioned concrete vaults became the only viable way to reduce the distance between the cave roof and the lawn while supporting the load above.

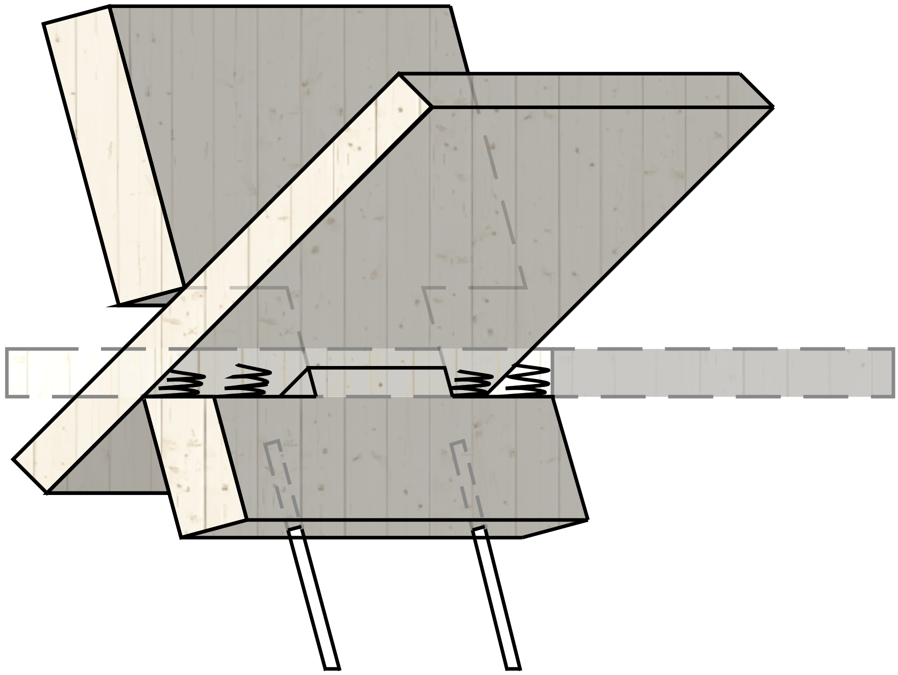
This approach results in a significant carbon footprint, both from materials and construction. To address this, we have explored alternative options for materials that are still undecided in the design.

Wood and Metals
Our material choices consist of concrete, stone, wood, and metals such as aluminium and steel. While concrete is impossible to recycle without adding more cement, metals are highly recyclable, and wooden panels can easily be reused since studs have standard dimensions.

This approach can be applied to the stage and back-of-house areas, using primarily metal and wood aside from smaller components and the elevator shaft. The result would be a structure made from recycled or reused steel, surfaces in reused or locally sourced wood, and roofing in recycled aluminium. This also reinforces the grounded, natural character of the design, with aged wood panels and intentionally imperfect details.



1:50 detail
Up to down:
1. Waterresistant film
2. Concrete layer 150 mm
3. Post stressed concrete beam 60x1800 mm, 2000mm apart
4. 20 mm repurposed sheet material (block resonation between the beams)
5. 150 mm flat steel truss, 1000mm apart
6. repurposed rubble 100-500 mm



Concrete
The cave walls and roof were originally lined with cast concrete shaped to resemble a cave. This helps address the concave geometry and slanted roof, which can create acoustic issues such as sound hotspots and dead zones. Instead, the textured form diffuses sound, producing a more even and balanced soundscape.

An alternative is to use reclaimed concrete from rubble. Its natural fractured surfaces are well suited to this purpose, as concrete often breaks with one flat side. These pieces can be mounted as panels with the flat face against the roof and the rough face exposed, mimicking a cave-like surface.
Remaining rubble can be crushed into smaller stones to fill out the surrounding hill or further processed into gravel.

Chairs
In total, around 3,000+ chairs are needed for the project. This represents a significant material demand, likely accompanied by emissions from long-distance transportation. The issue is worsened by the fact that furniture in the cave and in front of the stage will be exposed to weather, reducing its lifespan. A solution lies in using materials already available on site. Wood, and leftover rebar from construction can be repurposed to produce chairs locally. With a simple, repeatable design, they can be efficiently mass-produced while minimizing waste. Chairs are particularly suited for this approach, as their components are relatively small and adaptable.

By also making the chairs removable, they can be stored during the winter season when the orchestra is not in use, protecting them from the elements. Storage space is available both behind the stage and in wardrobe areas in the cave.

reflections

The design process

Designing the cave was an interesting challenge. It started out as our last concept, our "out there" concept. But we soon noticed this was the one that caught the attention of our classmates and teachers. It was the one that people remembered, the one that made them revisit childhood movies and stories. Most importantly, it sparked our and our acusticians interest. We had no other choice than to continue exploring the possibilities and difficulties of creating an underground musical experience for thousands of visitors.

The concept itself was clear, and we managed to never compromize it. In fact, it was almost impossible to even try, since making the cave smaller for example, would take away from all other aspects of the project by making the lawn area smaller, the distance to the stage longer and the proportions different.

We are happy with the way we met challenges in this project. For example, we needed to enlargen the volume of the cave to create a longer reverberation time, while still keeping the same distance to the back wall, since pushing it further back would create other acoustical issues. Through calculations we could raise the ceiling, while maintaining the sight lines on the lawn. These sight lines in both the cave and on the lawn were anther issue that needed precise design to ensure all seats are of good quality regarding both sound and view.

As we went, we realized that the concept in itself was a great solution to several issues. The terraces on the lawn, necessary for safe seating, help with errosion and drainage, and gives room to place higher vegetation that absorb sound. The entire hill helps blocking noise from the interstate from reaching the audience and stage, while also shielding the residential areas from noise from the event. We had many acoustical solutions on hand, such as reverberation chambers, helmholz resonators, absorbing materials, embankments and soft ground and vegetation, and we had loads of room to incorporate such solutions when needed. This made the design process relatively easy, and no issue felt impossible to combat.

For the visualizations we decided to create watercolour paintings by hand, to capture the storybook fairytale ambience that we tried to hold on to throughout the project.

Architectural qualities

A few of our main concepts are contrasts and flexibility, where we created two entirely separate experiences for the lawn audience and the seated audience in the cave, and great adaptability for the acoustics in the cave and on stage. This enables many architectural and acoustical qualities at once. All seats are realtively close to the stage and all 13 000 visitors have a clear view and hearing of the performance.

The cave also enabled us to hide supporting facilities behind the audience that are necessary for the large crowd. Our concept fits safety, necessities and communications in a natural way, inbedded in the cave-like atmosphere.

The stage and back of house has a shape that communicates with the hill, and contrasting materiality that amplifies the airy atmosphere of the outdoor areas. Inside, we have designed a functional workspace that prioritizes the well-being of the staff through easy access to bathrooms, spacious dressing rooms, lounge areas and efficient communication spaces without need for heavy lifting.

After our project was finalized we received a critique on the friday before submission to the competition. This entailed several points that both resonated with us but also created situations where sacrifices would be needed to remedy the issues brought up.

The largest critique concerned the slant of the cave roof. As previously mentioned this was a result of a need for a higher reverberation time that was directly tied to volume. A too broad volume would result in an echo feedback audibly noticeable to audiences so the only solution lay in raising the roof. This directly affected the slant of the hill and lawn, dictated by sightlines, which led us to a slanted design loosely following the slant of the hill to generate a reasonable acoustic environment while simultaneously constraining the hill to a reasonable height.

The problem presented itself as a feeling of a cut off view for audiences as if something was descending down upon them. While this strengthened the visual connections to a cave it could also be viewed as disruptive. A possible solution to this would be to dig down the stage, audience and cave further down allowing for a steeper hill but lower overall height, this would however create water drainage constraints.

Another possibility would be to draw back the roof to create an entirely horisontal vaulted roof. This would however decrease the amount of seats in the cave and push the lawn audience further away from the stage which worked against two core components of our project.

In the end we saw both the slanted roof as a quality of the cave like appearance and could neither find a viable solution in time which led to us to discard any changes for the final product. With more time or a complete workaround we could possibly find a solution given more time.

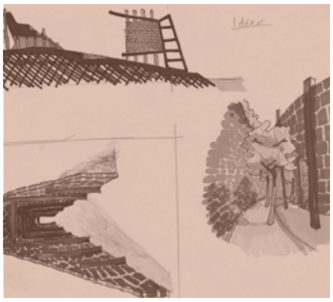
design tools and software used

5 meter sections

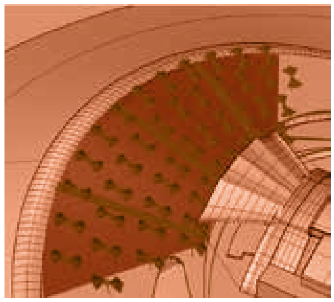
conceps models

clay models

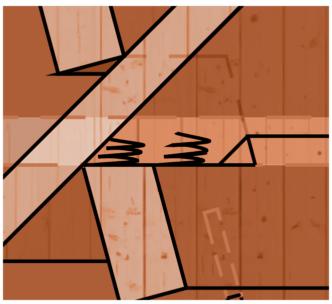
photoshop



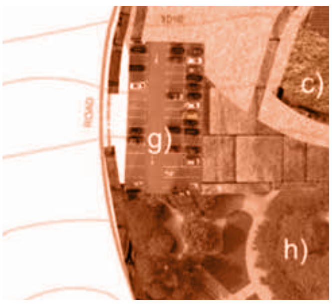
sketches



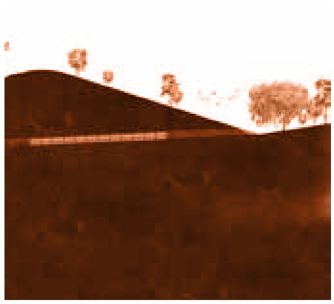
Rhino 3D



Affinity designer

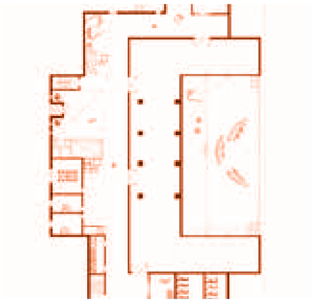


Affinity Publisher

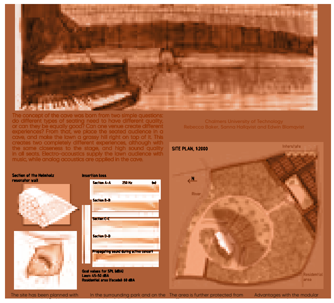


Affinity Photo

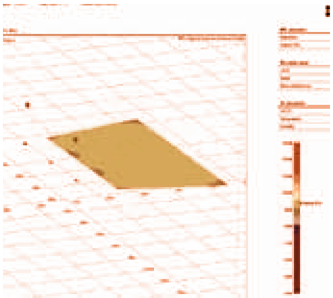
watercolour painting



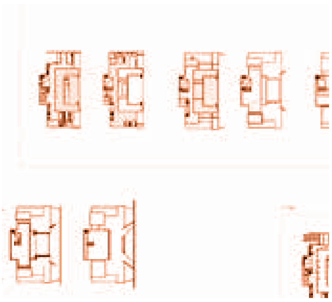
Illustrator



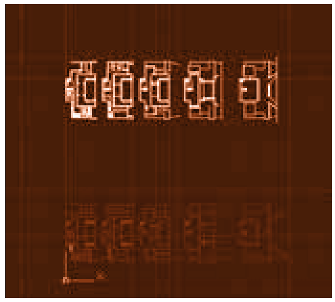
InDesign



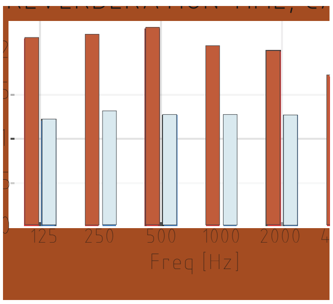
Audio-mapping programs



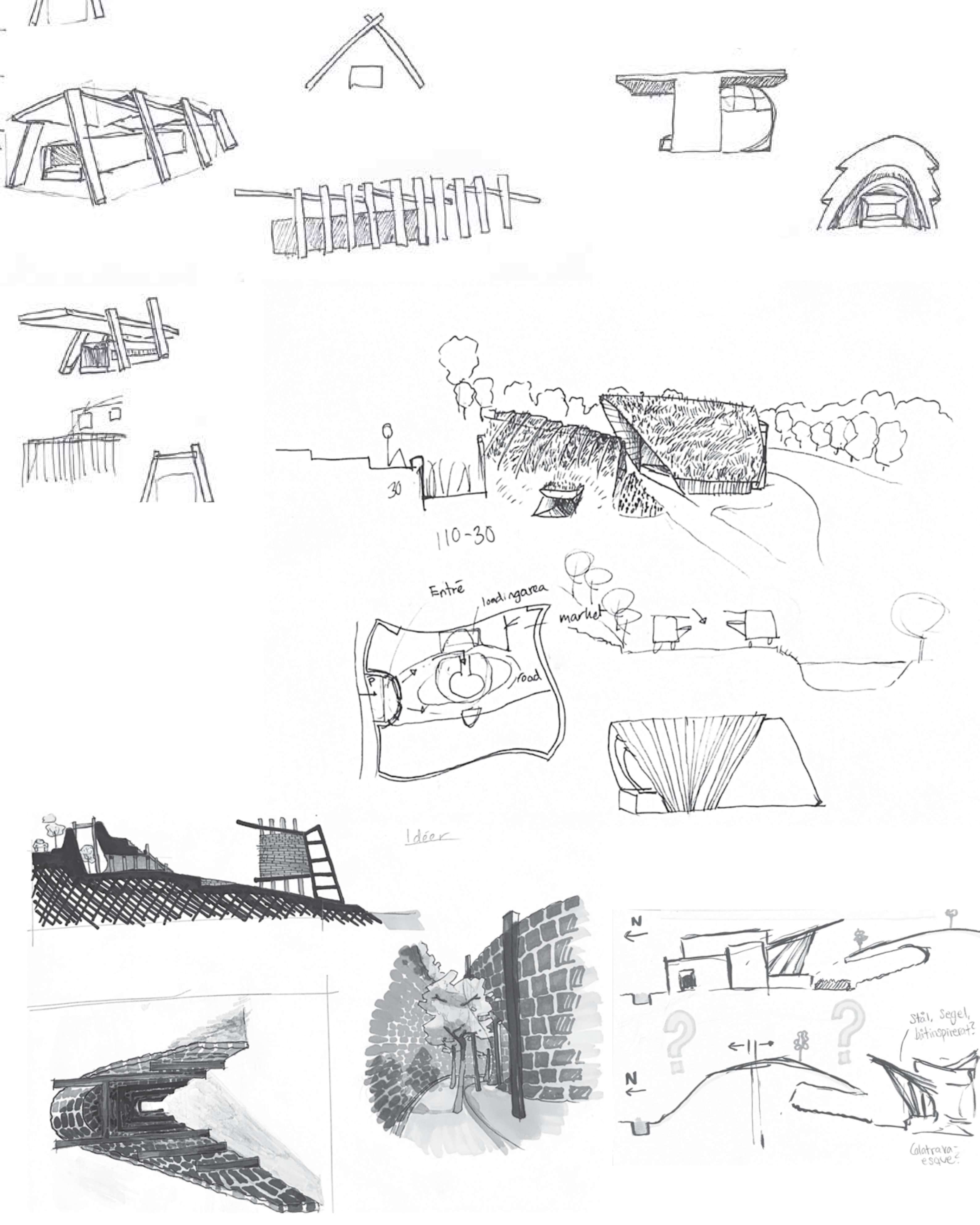
Rayon



Autodesk AutoCAD



Excel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110-30
Entré
loadingarea
market
P
road
Idéer
N
N
Stål, Segel,
båtinspirerat?
Calatrava-
esque?