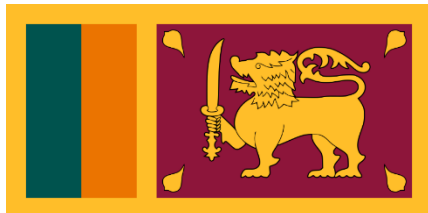


ASEAN Regional Seminar On Weather Modification 2024, Thailand

Rainmaking Technology Development in Sri Lanka

Past, Present and Future...



Eng. K.G.D.H.K. Jayasinghe
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(Dam Safety, Environment & Civil Structures Maintenance)
Ceylon Electricity Board



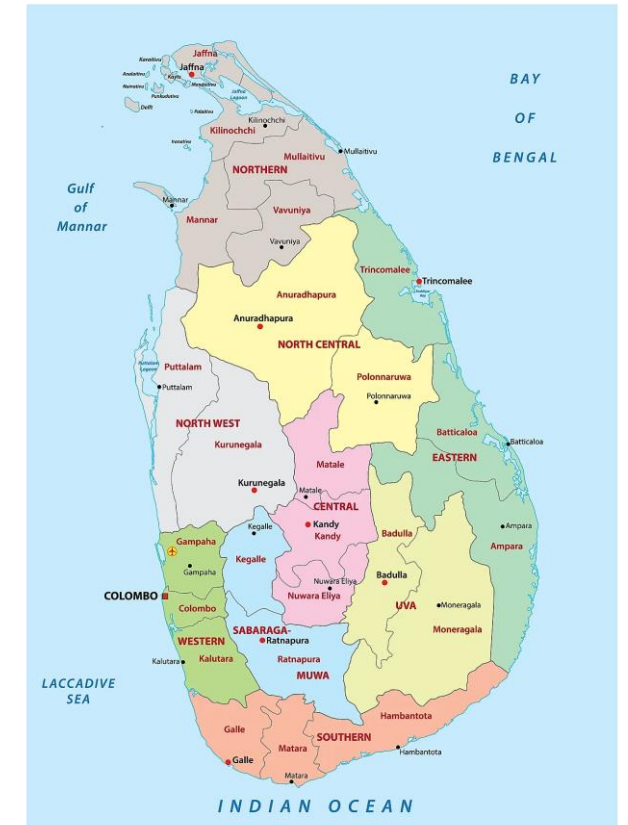
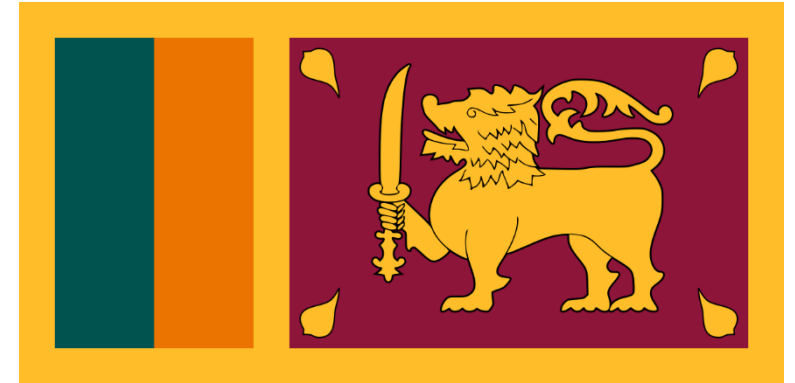
Outline

- ❑ Overview of Sri Lanka
- ❑ Importance of Rainmaking Technology Development in Sri Lanka
- ❑ Technical Corporation with DRRAA
- ❑ Present situation and Way forward

Overview of Sri Lanka

Overview of Sri Lanka

- ❑ Democratic Socialist Republic of Sri Lanka
- ❑ Capital:
 - Legislative City : Sri Jayawardenepura Kotte
 - Commercial City : Colombo
- ❑ Area: 65,610 km²
 - Divided into 9 Provinces & 25 Districts
- ❑ Population - 21.7 Million in 2020
- ❑ Official Languages - Sinhala & Tamil
- ❑ More than 3000 years of written history



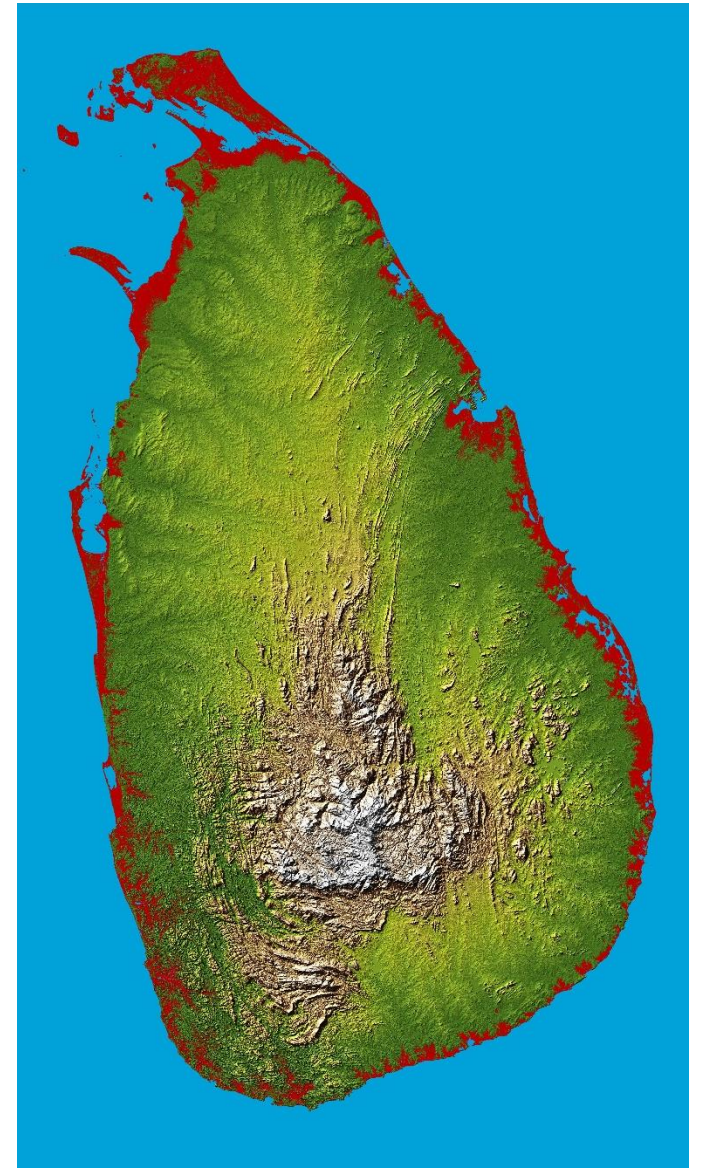
Geography

- ❑ Sri Lanka, an island in South Asia
 - Situated between, latitudes 5° and 10° N & longitudes 79° and 82° E.
- ❑ 103 rivers,
 - longest is Mahaweli River, extending 335 km
- ❑ 45 estuaries & 40 lagoons
- ❑ coastline is 1,585 km long
- ❑ rich in minerals such as ;
 - ilmenite, feldspar, graphite, silica, kaolin, mica and thorium.
 - Existence of petroleum and gas in the Gulf of Mannar has also been confirmed
- ❑ claims an exclusive economic zone extending 200 nautical miles,
 - which is approximately 6.7 times Sri Lanka's land area.



Climate & Topography

- ❑ Climate is tropical and warm because of moderating effects of ocean winds
- ❑ Topography
 - The central part of the southern half of the island is mountainous with heights more than 2.5 Km.
 - The core regions of the central highlands contain many complex topographical features such as ridges, peaks, plateaus, basins, valleys and escarpments.
 - The remainder of the island is practically flat except for several small hills that rise abruptly in the lowlands.



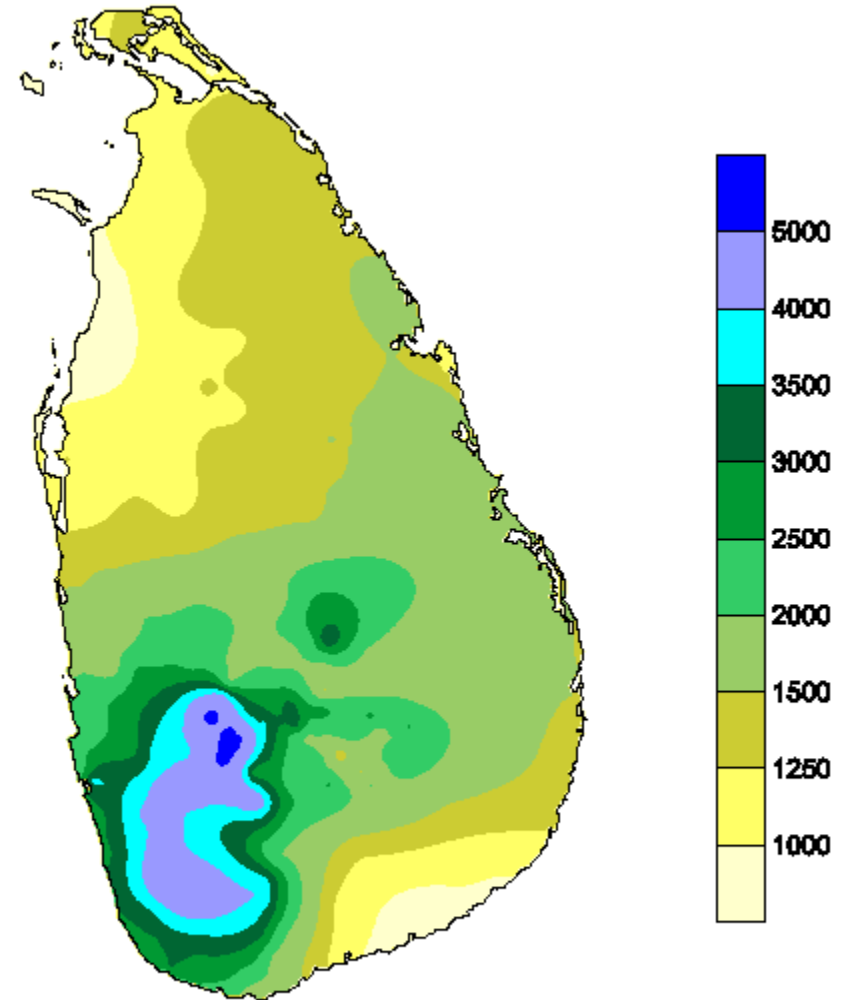
Temperature & Rainfall

□ Temperature

- The mean annual temperature varies from 27°C in the coastal lowlands (up to and altitude of 100 m to 150 m) to 16°C at Nuwara Eliya, in the central highlands (1900m above mean sea level).
- This relatively unique feature manifesting as sunny beaches to rain forests inland is a tourist attraction.

□ Rainfall

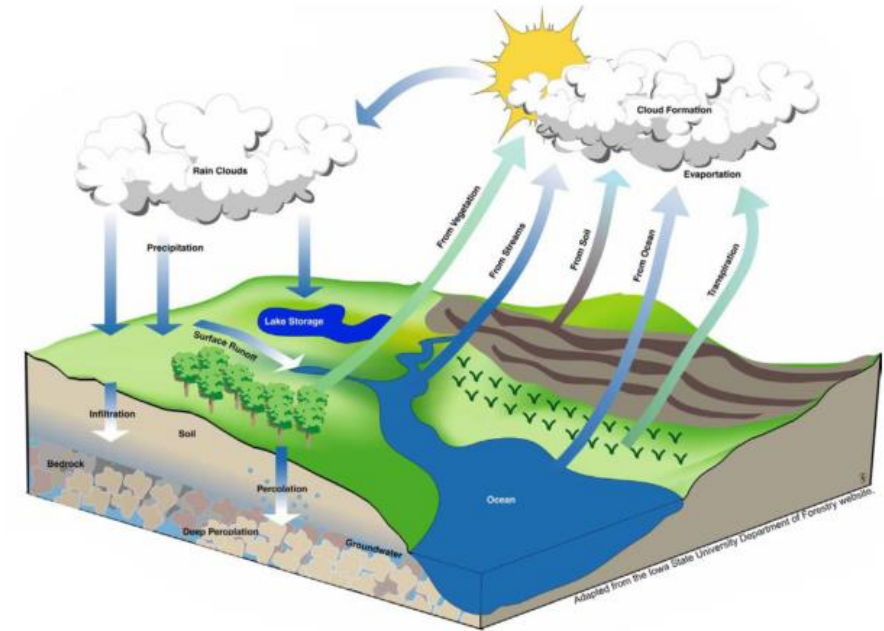
- Rainfall in Sri Lanka has multiple origins.
- Monsoonal, Convective and depression rain accounts for a major share of the annual rainfall.
- The mean annual rainfall varies from under 900mm in the driest parts (southeastern and northwestern)
- over 5000mm in the wettest parts (western slopes of the central highlands).



Importance of Rainmaking Technology Development in Sri Lanka

Need of Rain Management

- Extreme weather conditions
 - Floods vs Droughts
- Failure of Monsoons
 - Less rainfall
- Having the required rain at correct place at correct time



Sectors benefited by Rainmaking Development



Agriculture

- Two Sub sectors
 - Plantation sector: tea, rubber and coconut – 24% from total agricultural lands
 - Non plantation sector: paddy, other cereal crops, oil crops, vegetables, fruits, etc. – 76%
- 12% of Gross Domestic Product (GDP)
- 22% of total exports
- 25% of employed labour force



Hydropower Generation

- Total Installed Hydropower Capacity in SL (Major Hydro & Mini Hydro) - 1832 MW
- 41.8% from total installed capacity in SL
- Total Hydropower Generation in SL (In 2023) – 5,951 GWh
- 38.2% of total energy generation in SL in 2023

Overview of Hydropower Generation in Sri Lanka

Power Generation Statistics in Sri Lanka

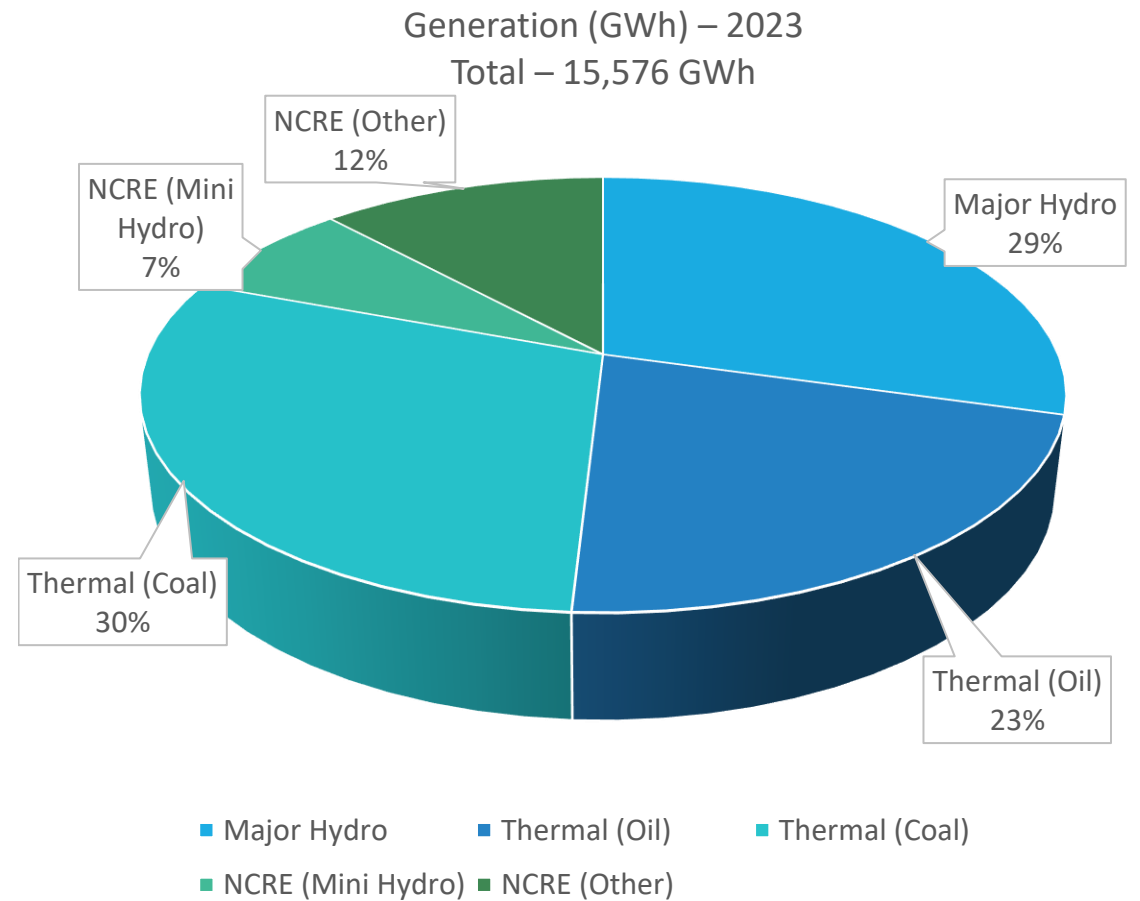
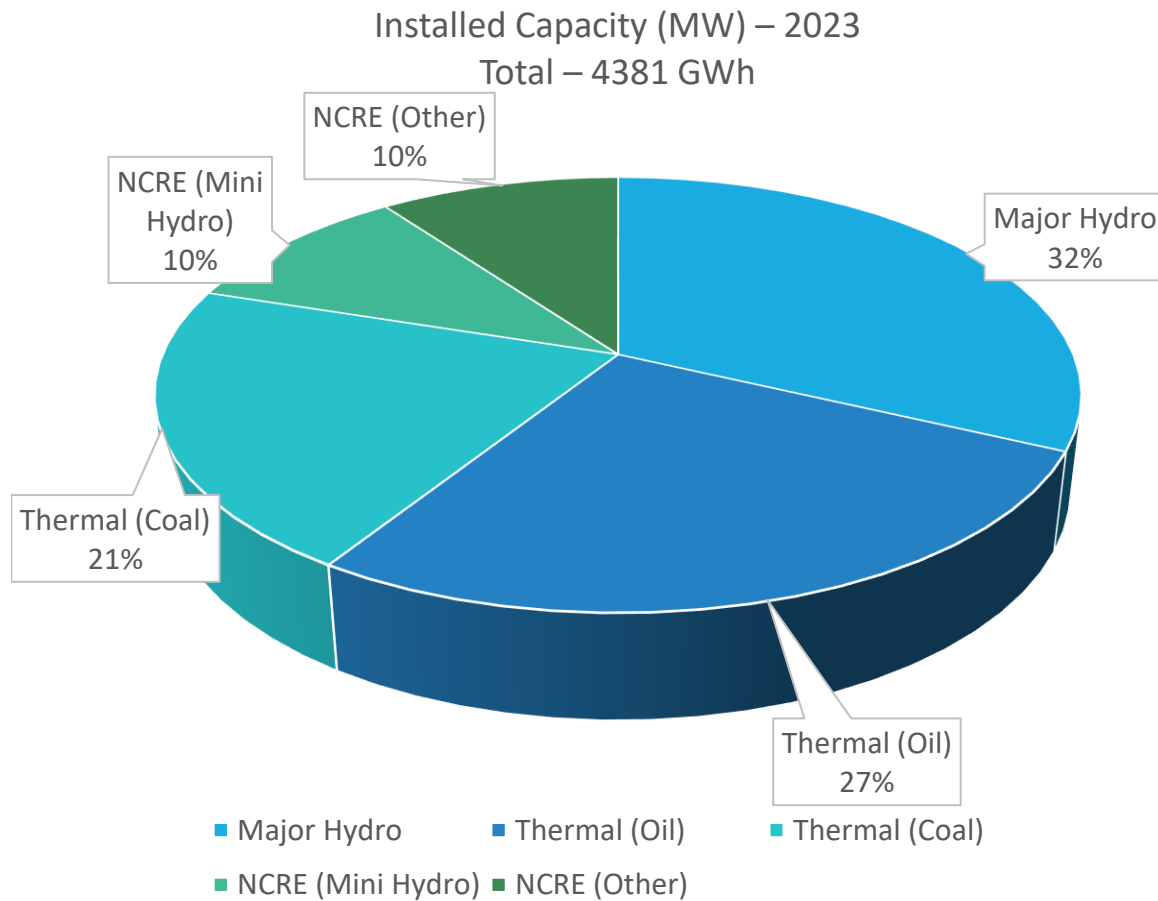
Ownership & Type of Power Station		No of Power Station	Installed Capacity/ (MW)
CEB	Total	30	3,218
	Major Hydro	18	1413
	Thermal (Oil)	10	801
	Thermal (Coal)	1	900
	NCRE (Wind)	1	104
IPP	Total	334	1,163
	Thermal (Oil)	3	387
	NCRE (Mini Hydro)	212	419
	NCRE (Wind)	19	163
	NVRE (Others)	14	54
	NCRE (Grid Connected Solar)	86	139
Total			4,381

- Total Installed Hydropower Capacity in SL in 2023 (Major Hydro & Mini Hydro)

- 1832 MW

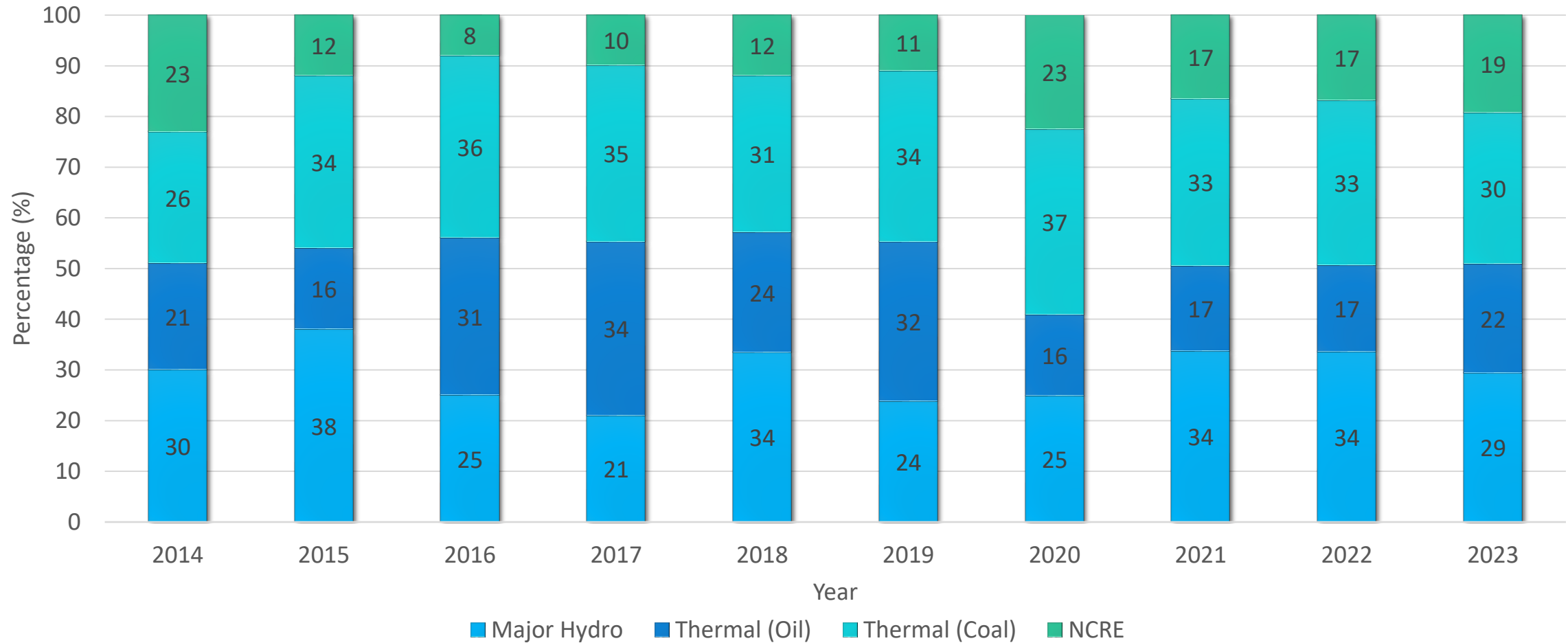
- 41.8% from total installed capacity in SL

Electricity Generation in year 2023



NCRE – Non Conventional Renewable Energy

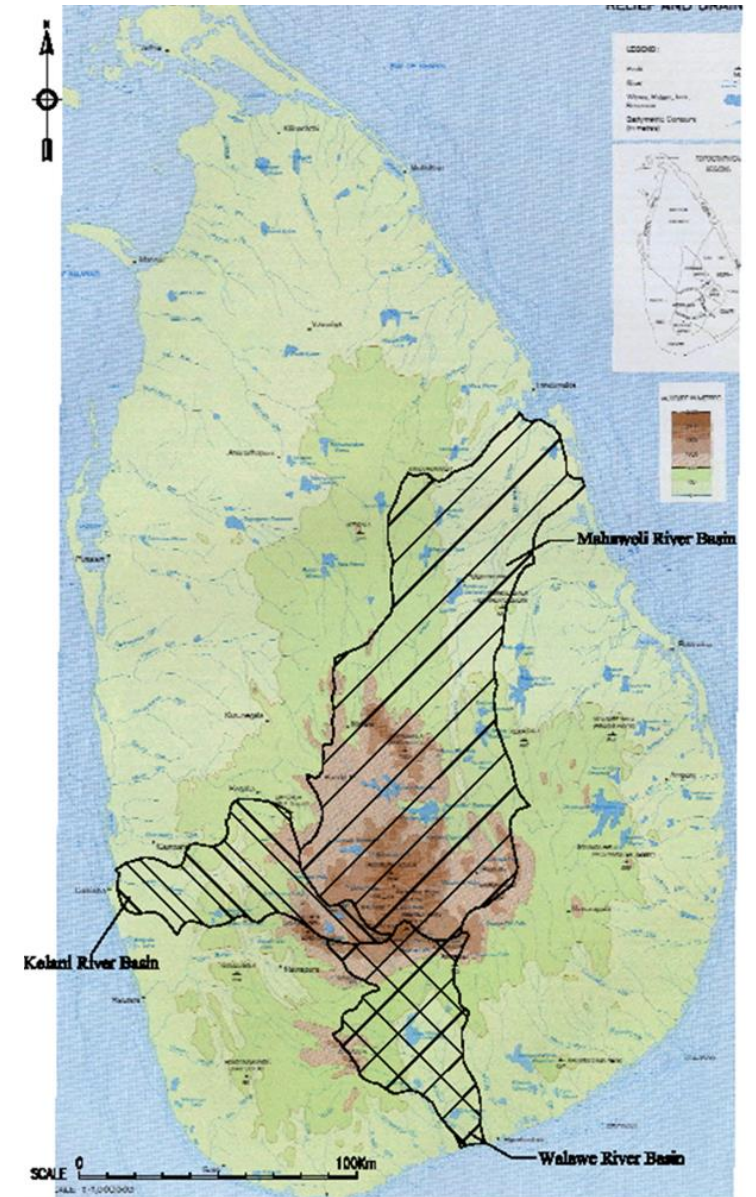
Electricity Generation by Types (2014-2023)



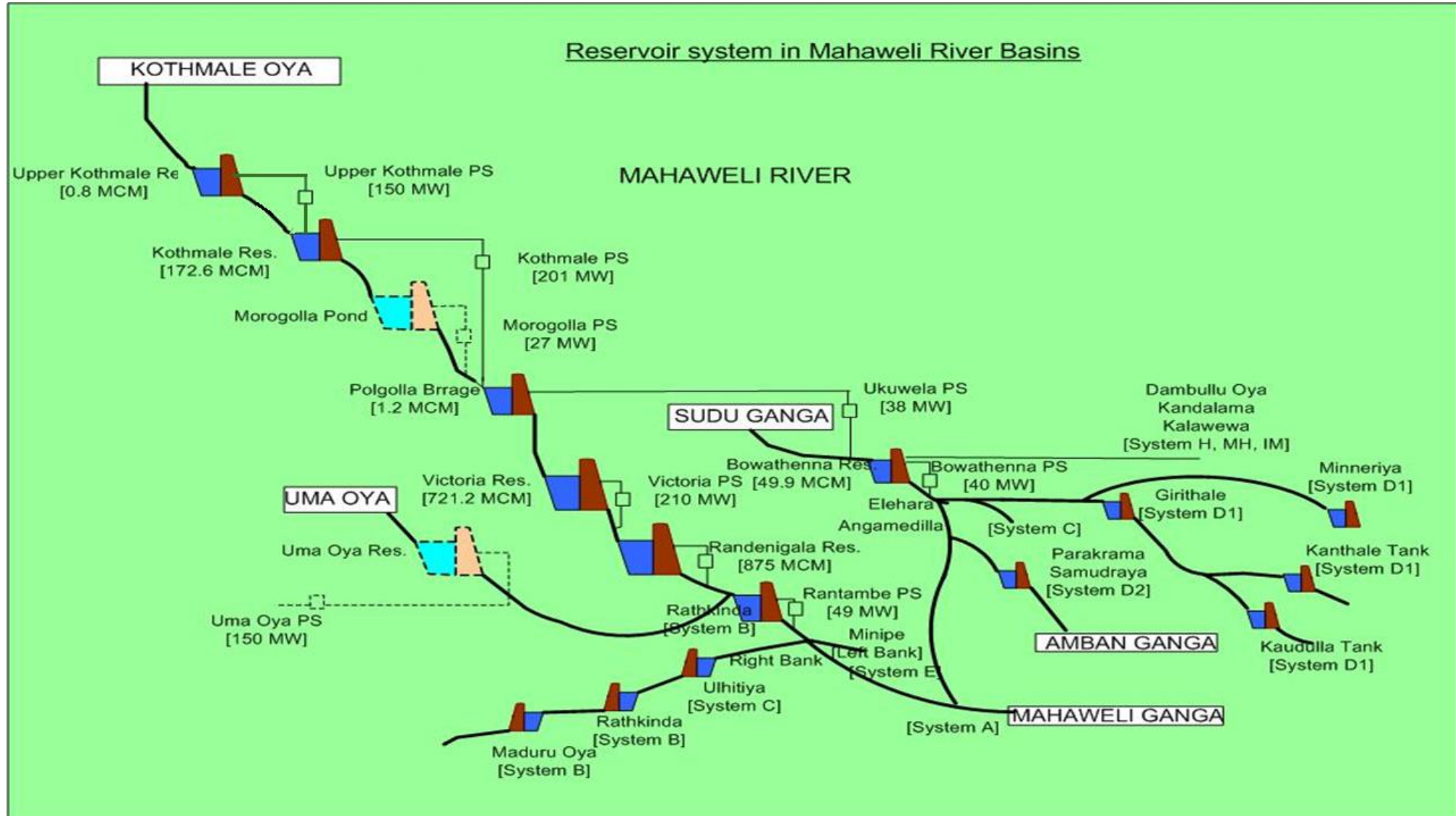
NCRE – Non Conventional Renewable Energy

Hydropower Generation in SL

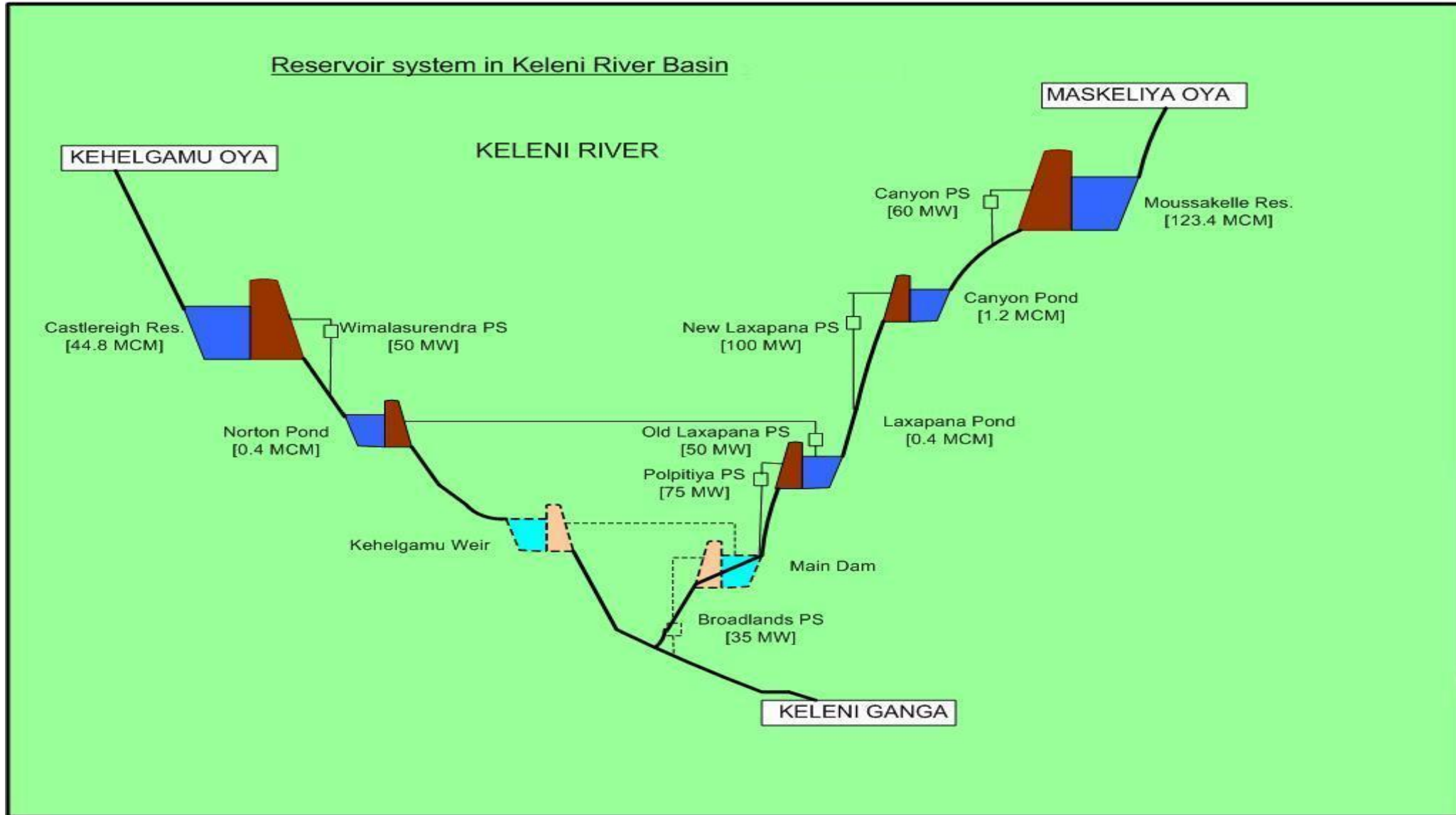
- ❑ Annual Energy Generation in SL (In 2023) - 15,576 GWh
- ❑ Total Hydropower Generation in SL (In 2023) – 5,951 GWh
- ❑ 38.2% of total energy generation in SL
- ❑ Major river basins for large scale hydropower development
 - Mahaweli river basin
 - Kelani river basin
 - Walawe river basin
 - Kalu river basin



Mahaweli River Basin

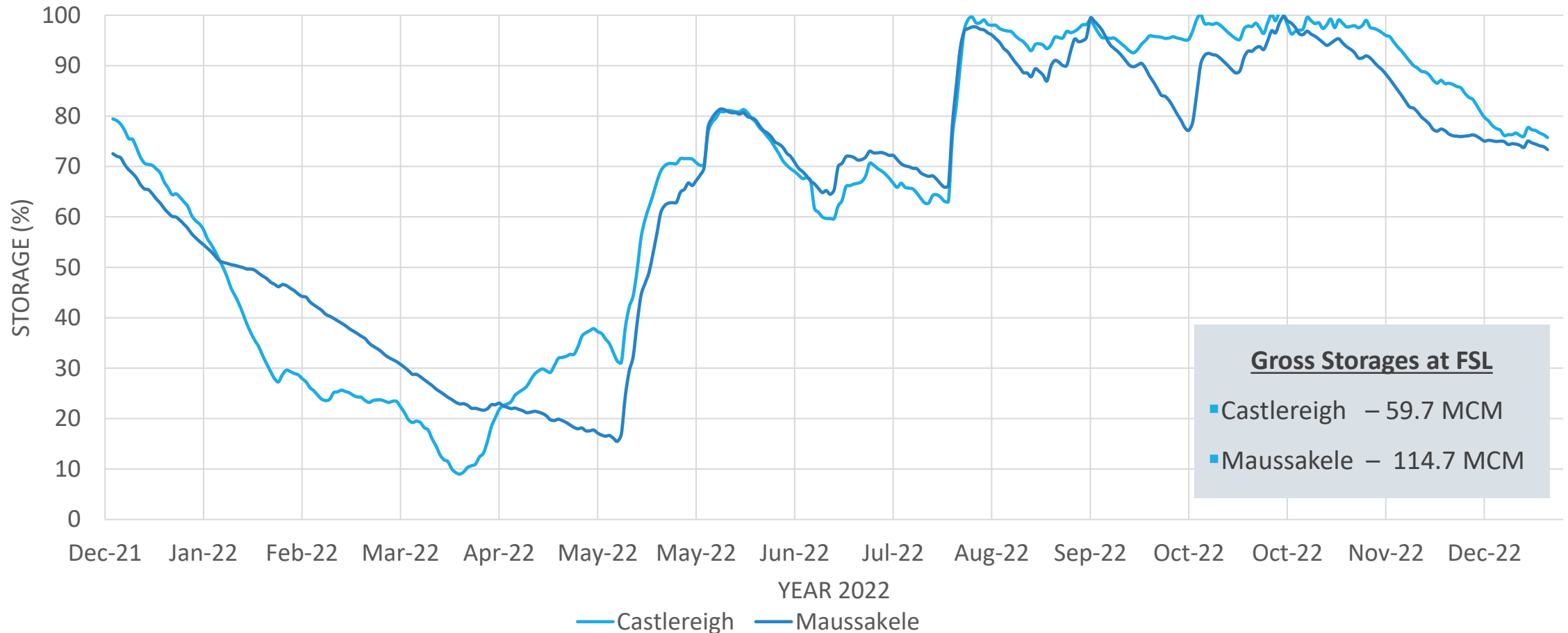


Kelani River Basin



Storage variation of Major Reservoirs

STORAGE VARIATION OF CASTLEREIGH AND MAUSSAKELE RESERVOIRS IN YEAR 2022



Technical Corporation with DRRAA - Thailand

Historical Collaboration in 1980...

- ❑ In 1980, SL requested the assistance of experts from Royal Rainmaking Research and Development Institute (RRRDI) of Thailand due to insufficient precipitation in the catchment areas.
- ❑ Two teams of Thai experts visited SL in June 1980.
- ❑ Trail operations had been conducted over the hydropower reservoirs of Castlereigh and Maussakele.

Thais will seed clouds tomorrow

The 'seeding' of clouds over the Mousakelle and Castlereigh reservoirs gets underway tomorrow morning when three Thai experts headed by Thailand's pioneer rain maker Dr. Devakul commence a second series of experiments to induce rain over the catchment areas.

The experts including Lieutenant Colonel Thamoon, one of the experts of the previous rain making team who seeded clouds over the reservoirs last month arrive in Sri Lanka today.

A chemical grinder to mix the chemicals necessary for the operation will be brought down by the Thai team. During the last operation the experts used the Ceylon Ceramics Corporation's grinder.

While Air Force personnel, CEB officials and officials of the Meteorology Department will assist in the operation, the modified Dakota used in the previous 'seeding' of clouds will be used for this project too.

Meanwhile the United Nations Development Programme (UNDP) has agreed to finance the training of Sri Lankan scientists in the technology of rain making.

A team of 'trainees' comprising scientists from the Meteorology Department and the CEB will leave for Thailand shortly to receive a full training in rain making.

The UNDP, these sources said, had volunteered to fund this project because it is expected to cost large sums of money and since such a rain-making team is necessary for the country's development.

Ceylon Daily News

The English Daily with the largest circulation in Sri Lanka

in Sri Lanka VOL. 65. NO. 148 MONDAY, JUNE 23, 1980. 24 PAGES

Thai rain-makers break back of worst drought

By Ravindran Casinader

The two Thai rain-maker experts have helped Sri Lanka to break the back of its worst drought this century.

Since their two sorties on Saturday, spraying the clouds with rain-inducing chemicals sodium chloride, ammonium nitrate, urea and calcium chloride — rain has been falling in the hill country catchment areas of the hydro-power reservoirs. There was rain on Saturday afternoon and again in the evening.

"There was heavy rain in the evening and intermittent rain throughout the night", a Met Department spokesman said.

"There is nothing to worry about now. It is raining heavily here", an officer on duty at the Mousakelle reservoir told me on the telephone on Saturday night.

As rain continued to fall again yesterday, a CEB spokesman said: "The worst is behind us. However, we are not taking any chances, and there will be no change in the power-cuts till we have an appreciable amount of rain", he said.

The Thai rain experts Dr. Metha Rajahapiti and Lt. Col. Thamnoon Singhajet did two sorties on Saturday impregnating the clouds with the chemicals from an Air Force Dakota.

The Operation Task Force met at the Prime Minister's office yesterday morning to evaluate the mission and told the Prime Minister's secretary and the mission's co-ordinator Bradman Weerakoon that the experiment had been a success. The cloud-seeding mission had definitely enhanced the rainfall in the catchment areas, they said.

Dr. Metha Rajahapiti, who headed the operation at the end of the mission, "We are extremely pleased", he said, "and very much impressed with the high degree of efficiency with which your men from the Air Force, the Ceylon Electricity Board and the Met Department worked on this mission under the smooth co-ordination from your Prime Minister's office".

The Thai rain-makers will repeat their operation tomorrow at the request of Prime Minister R. Premadasa.

(Pictures on page 11)

Following cloud-seeding operation Heavy rain in catchment area

Heavy rains were reported in certain areas in the Castlereigh and Mousakelle reservoir catchment areas yesterday evening, after the three Thai experts carried out their cloud-seeding operation over the two reservoirs.

Ground observation units set up in the target area by the Air Force and the Met Department said that rain began to fall after the Thai experts made two cloud-seeding flights from 10.10 a.m. to 12.30 p.m. and 3.15 to 4.15 p.m. The Sri Lanka Air Force's DC 3 and Dove aircraft were made use of for the operation.

Prof. Debriddhi Devakul, Head of Thailand's Royal Rainmaking Research and Development team and his two assistants Lt. Col. Thamnoon Singhajet and Mr. Watana Sukhanaset who arrived here on Monday night at the request of the Sri Lanka Government used sodium chloride, calcium chloride, ammonium nitrate and urea, for their operation.

Thailand's Ambassador in Sri Lanka, Miss. Ampia Bhanak accompanied the experts on their first sortie. The Thai rain-makers were assisted by the Sri Lanka Air Force, the Met Department and the Ceylon Electricity Board.

The operation was co-ordinated by the Prime Minister's Secretary, Eradiman Weerakoon.

The experts will repeat their operation today and tomorrow.

Reservoir water levels up Power-cuts reduced by two hours

The present islandwide power cuts have been reduced by two hours (one hour in the morning and one hour in the evening) from today, following an increase in the water levels of both the Castlereigh and Mousakelle reservoirs.

Mr. James Lamerolle, Secretary, Ministry of Power and Energy said yesterday.

The present power cuts in the city are 6.20 to 8.30 in the morning and 3 to 6 in the evening. Outside Colombo the power cuts are imposed at varying times.

The power cuts from today will be 7.40 to 8.30 in the morning and 4 to 6 in the evening. Outside power cuts have also been reduced by two hours from today.

Mr. Lamerolle said that the Director of the Meteorological Department was of the view that the current rains would continue for a few days more. It had therefore been decided to reduce the present power cuts by two hours.

Both reservoirs yesterday contained the water equivalent of 71.4 million units of electricity, a significant increase since July 11, when it was 42 million units approximately and from July 11-12 had been raining. This reservoir has been the lowest level recorded during the periods of drought for the last five years.

Mr. Lamerolle said that the situation was that the reservoirs had only 23 per cent of their capacity. "We will like very much to build up some more reserves of water. But we are relaxing the present power cuts by two hours because of widespread rain and also following complaints from various quarters about the inconvenience caused by power cuts. The Electricity Board too was looking forward to this."

"We will however watch the situation further and if the reserves of water do not build up we may have to reintroduce the five hour power cut to build up the reservoirs," he said.

(See "Thai rain-makers try again" on Page 11).

Thai rain-makers try again

The three Thai experts leave for the Castlereigh and Mousakelle catchment areas today to induce rain artificially to augment the country's hydro-power.

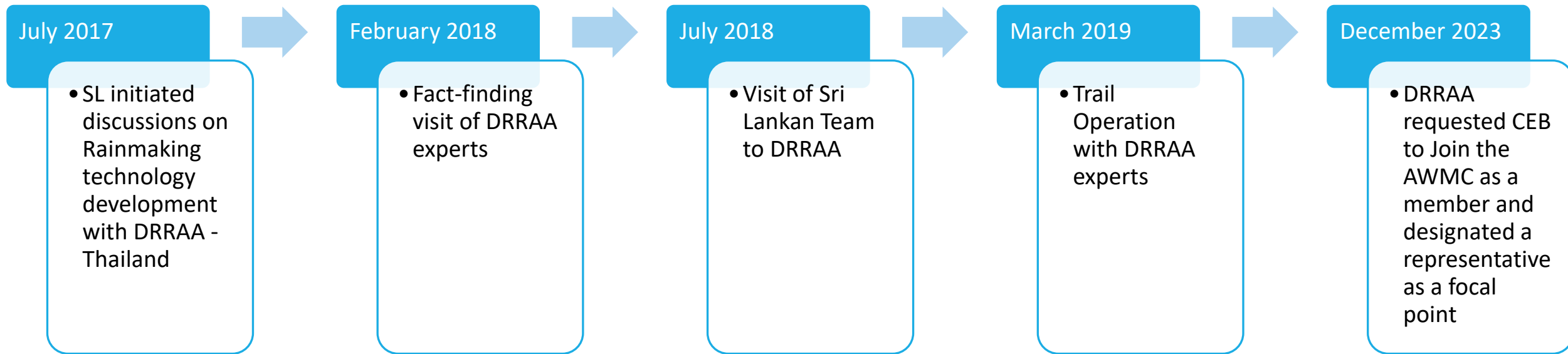
The total energy in the two hydro-power reservoirs increased to 71.4 GWH yesterday as against 69.7 GWH the previous day. But that was not sufficient, Ceylon Electricity Board sources said.

Prof. Debriddhi Devakul, head of Thailand's Royal Rain-making Research and Development Team and his two assistants Lt. Col. Thamnoon Singhajet and Mr. Watana Sukhanaset who arrived here on Monday night will carry out their operation today in three cloud-seeding flights. Unlike last time, they will use two Air Force Dakotas today. They have also brought a special chemical grinding machine from Thailand for this purpose.

Prof. Devakul, who is an experienced pilot himself, said he would concentrate on training our pilots this time on special flying techniques needed for cloud-seeding operations.

The second experiment had failed last time as the high velocity of winds had pushed the seeded clouds beyond the target area. The two aircraft which will be used today, will reduce the time-lag between sorties and enable the experts to encourage the clouds to rain immediately.

Collaboration since 2017...



Fact-finding mission of DRRAA experts

- DRRAA experts visited SL on 19 – 22 February 2018
- Discussed with agencies involved in water resources management
- Visited the Meteorological department of SL, Sri Lanka Air Force - Rathmalana & catchment areas



Visit of the Sri Lankan Technical Team to DRRAA

- Technical committee of SL visited DRRAA on July 2018
- Committee represented all the key agencies in water resource management in SL



Trial Operation - 2019

- Four experts from DRRAA visited SL on 20-30 March 2019 for the 1st trial operation
- Catchment area of Castlereigh and Maussakelle reservoirs was selected for the trial operation.
- CEB planned to perform further trial operations in Nov 2019 and Nov 2023, however, no operations were done



Present Situation and Way Forward...

Challenges for Rainmaking Operations in SL

- Unavailability of aircraft
 - SLAF and CEB have a MOU for the aircraft operation
 - Limited no of Y12 aircraft are available in SLAF
- Issues in monitoring and forecasting of weather
 - Unavailability of weather radar
 - Financial issues in Meteorological Department

Present Situation

- Have assigned a dedicated branch in CEB to conduct trial operations

Way Forward...

- Assigning of a separate team for trail operations
- MOU between stakeholder organizations
- Mutual collaboration with DRRAA, AWMC, etc. to obtain trainings and sharing knowledge

Trial Operations and Experiences

Outline

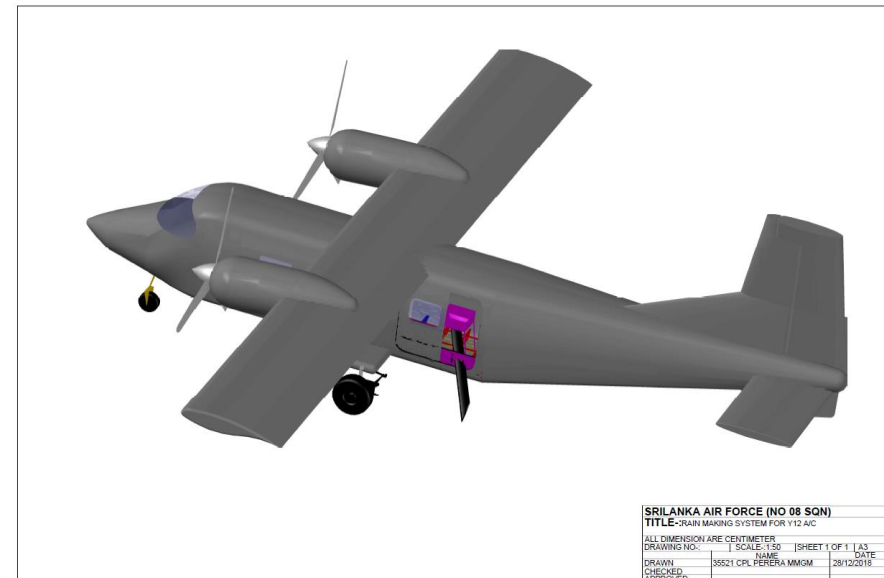
- ❑ Aircraft Modification
- ❑ Materials
- ❑ Monitoring of Weather
- ❑ Results

Aircraft Modification

Aircraft Selection

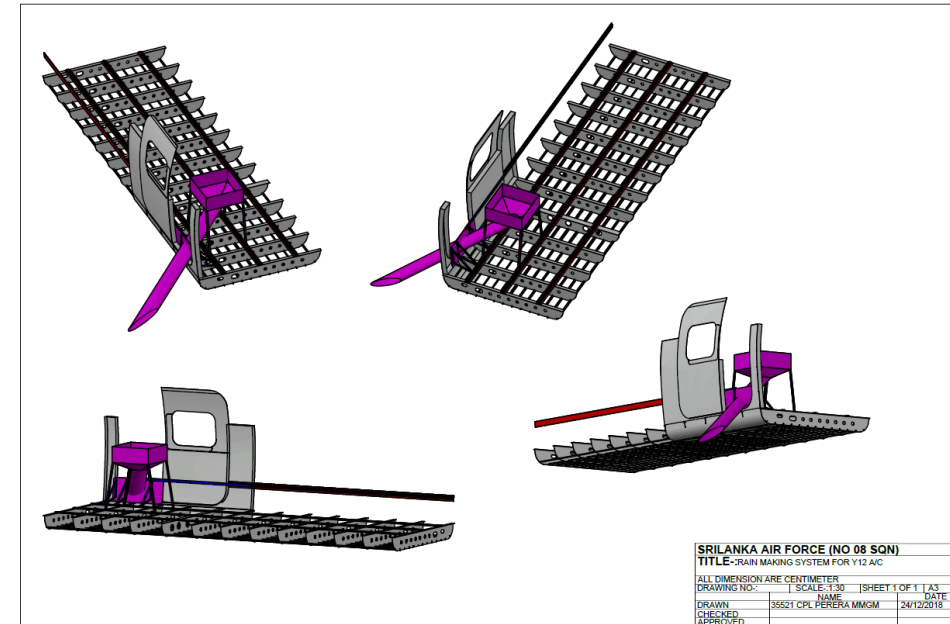
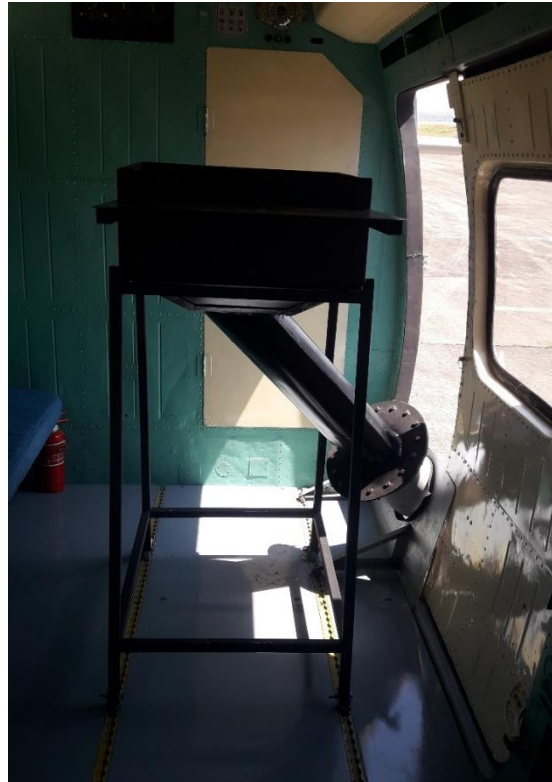
- Required characteristics of the aircraft
 - Aerial delivery system
 - Cargo carrying capability
 - Good maneuverability
 - Ability to operate in weather

Y-12 aircraft of SLAF was modified to deliver substances



Aircraft Modification

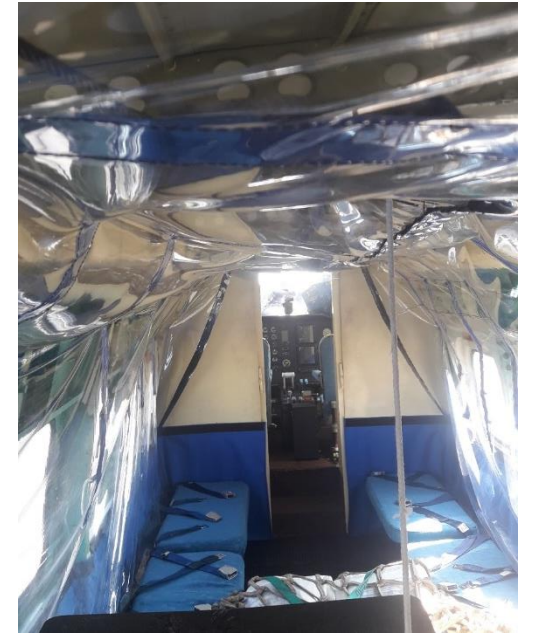
- Substance Release Unit (SRU)
 - Removal of door and installing the modification to the aircraft



Aircraft Modification

- Corrosion Protective Measures
 - Seeding materials are highly corrosive in nature

- Loading
 - Need to keep load steadily



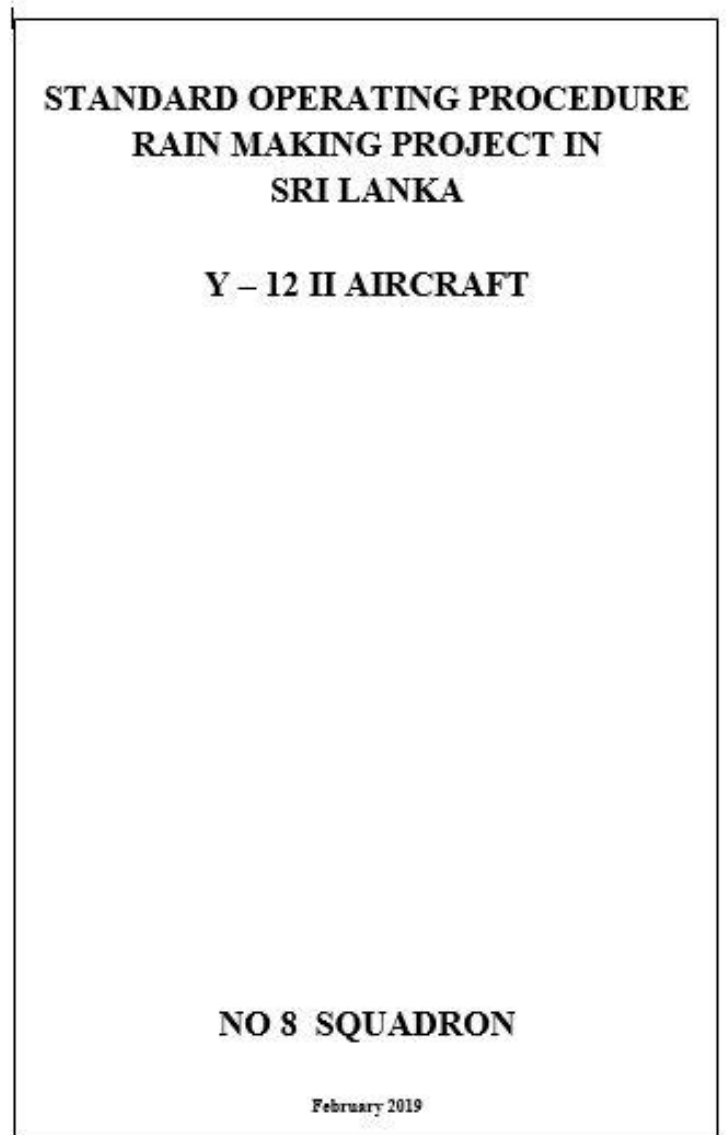
Aircraft Modification

- Intermediate Platform
 - To reduce the seeder's fatigue
- Personnel Protective Equipment
 - Sensation of burning, chocking and sore eyes



Aircraft Modification

- Standard Operating Procedure (SOP)
 - All are following the same procedure



Materials

Materials used for Trial Rainmaking Operations

- 3 main types of cloud seeding materials used for rainmaking Operation

Cloud Condensation Nuclei (CCN)

- Provides the surface for water vapor molecules to condense into liquid form
- Industrial Salt (NaCl) was used

Exothermic

- Enhances the environment temperature by releasing heat to the surroundings, thus the atmospheric temperatures or cloud temperatures go up
- Calcium oxide (CaO) was used

Endothermic

- reduces surrounding temperature by absorbing heat from the surrounding to activate or enhance the formation and growth of cloud droplets.
- Urea and Dry Ice were used

Materials used for Trial Rainmaking Operations

Industrial Salt (NaCl)

- Sodium Chloride (NaCl) shall be greater than 95% by weight
- Grain size - more than 97% shall pass through 425 μ m sieve and more than 50% shall pass through 250 μ m sieve.
- Relative Humidity shall be less than 0.6% by weight

Calcium Oxide (CaO Powder)

- CaO shall be greater than 95% by weight.
- Grain size - more than 95% (by weight) shall pass through 125 μ m sieve.
- 100g of CaO in 100 ml of water shall increase the temperature of the solution at least by 70 OC
- Relative Humidity shall be less than 0.6% by weight

Urea (CH₄N₂O Prill)

- Nitrogen (N) content shall be greater than 46% by weight.
- Total biuret-N must be less than 1% by weight
- pH value must be higher than 7 (1.2 wt/Vol)
- Grain size – Prill

Dry Ice (3mm pellets)

- Grain Size : Shall be in 3 - 5 mm size

Monitoring of Weather

Monitoring of Weather

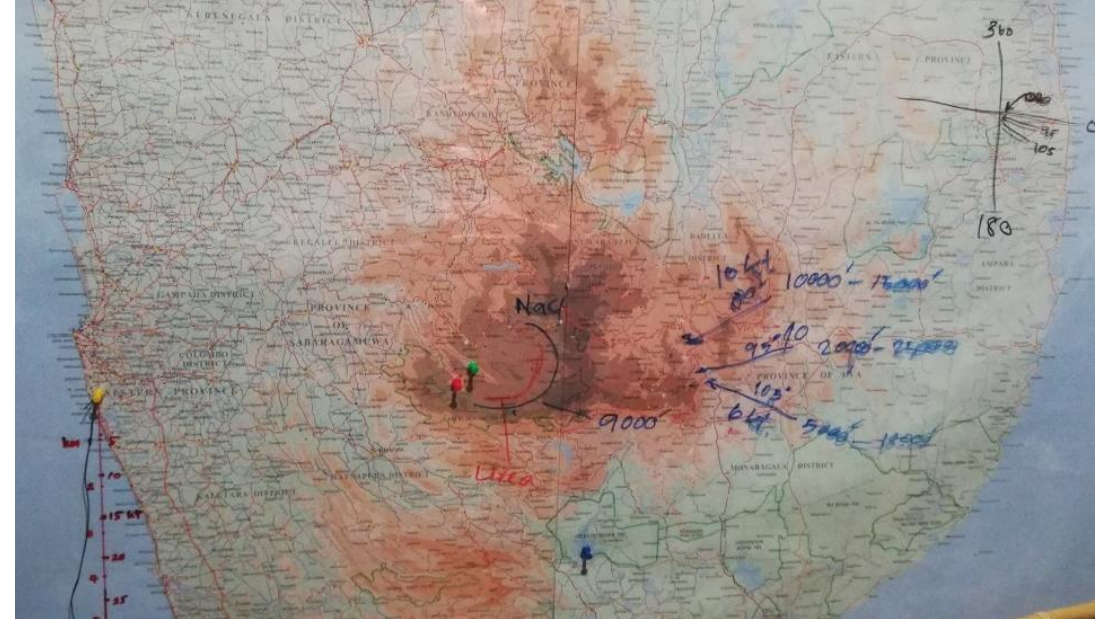
- Radiosonde Data is available in Meteorological Department of Sri Lanka
 - Radiosonde is an electronic device attached the balloon and radio transmitter to report temperature, humidity, air pressure, air direction, and air velocity in each layer of the atmosphere/ of atmosphere in each level.
- Normally operated twice a week/ once in 3 days period at 11:30 am
- Daily operated during the trial period at 08:30 am
- No weather radar is available in Sri Lanka

Rainmaking Trial Operations

Rainmaking Trail Operations

Day 01 [March 22, 2019]

- Avg. relative humidity at 10,000 - 18,000 ft was quite low

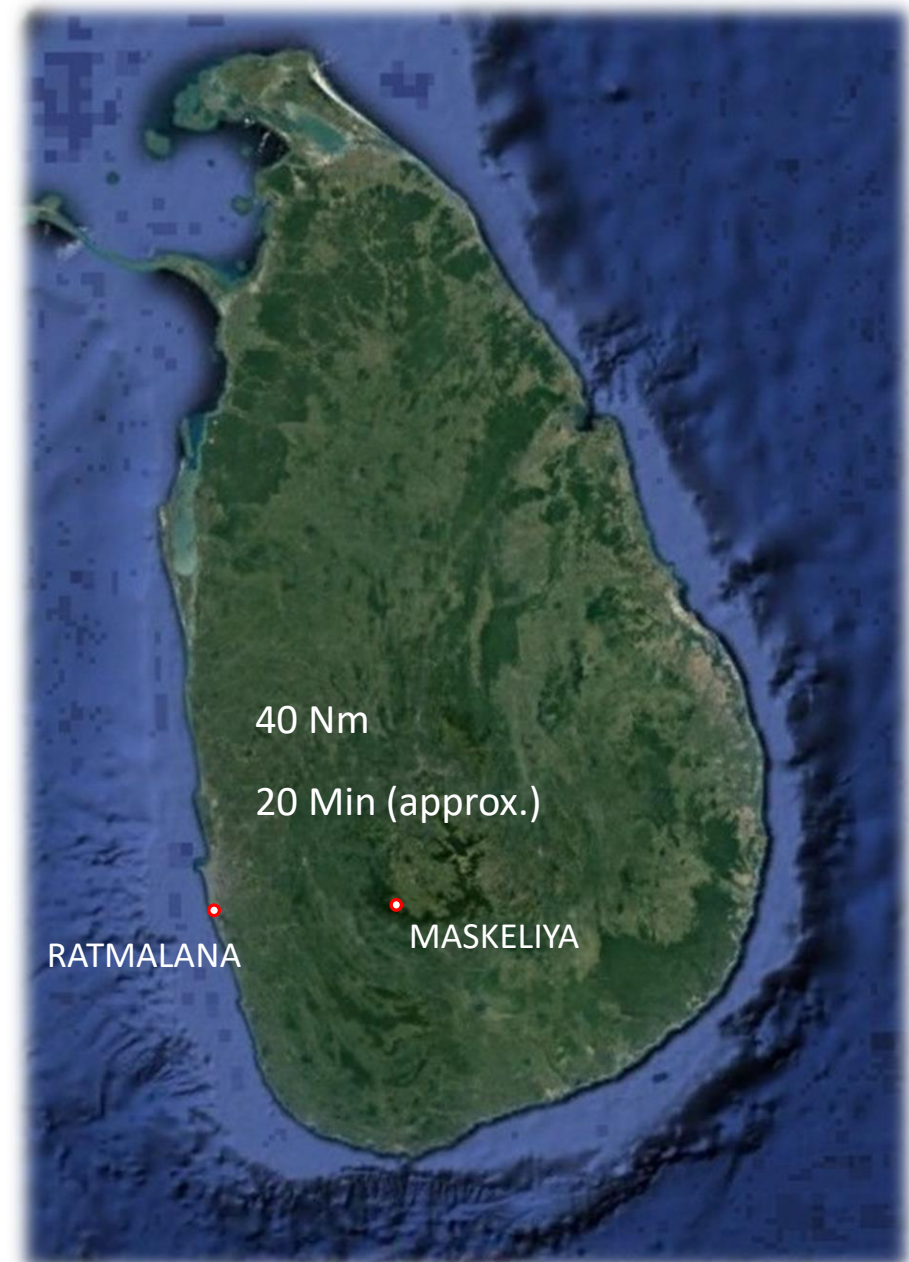
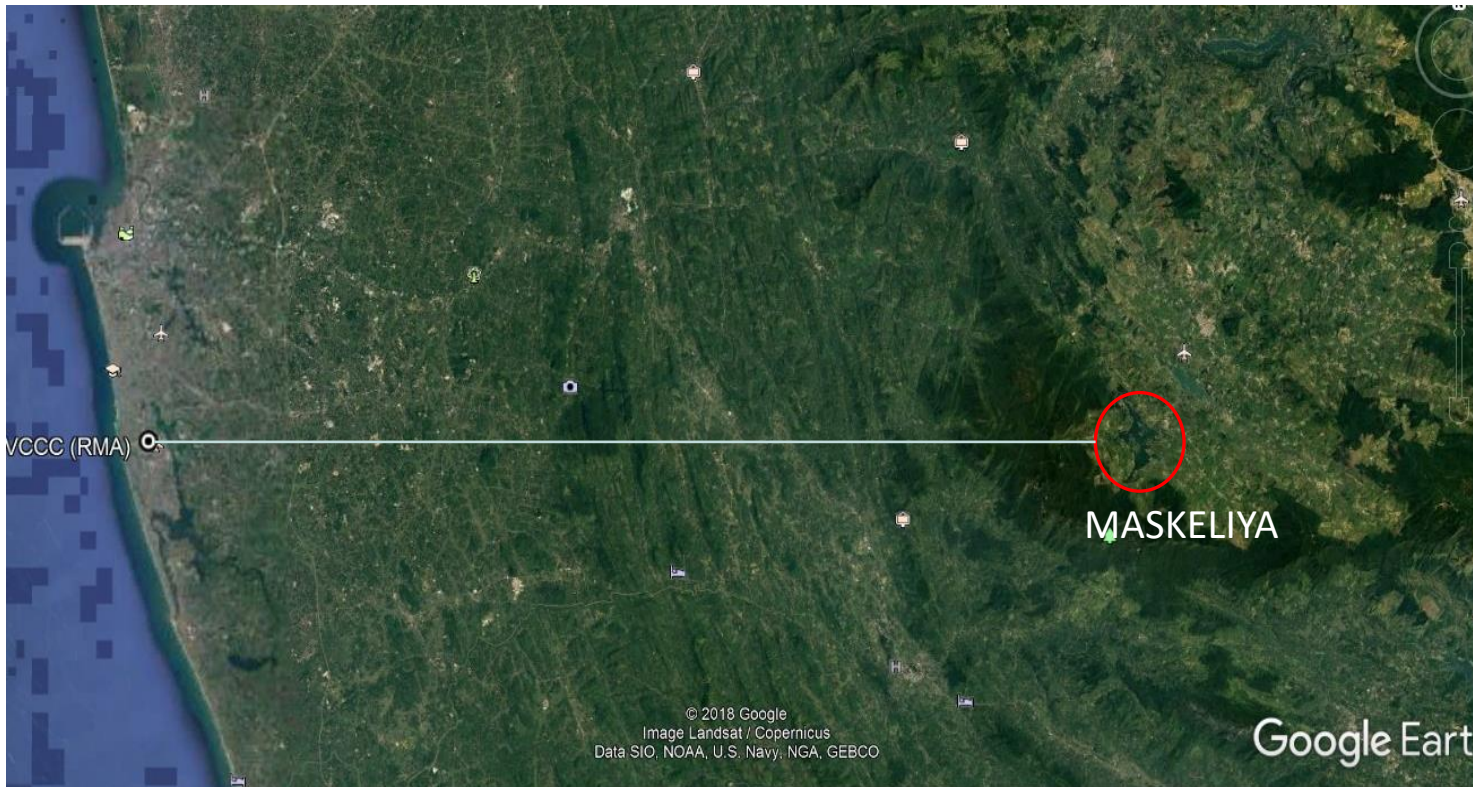


Upper-air observation data	
Relative humidity (surface - 10,000 ft.)	65.7%
Relative humidity (10,000 ft. - 18,000 ft.)	36.6%
Average wind speed (5,000 to 10,000 ft.)	6 kn.
SI	3.0
LI	-0.3
KI	30.5

Step	Take Off Time	Landing Time	Material Used	Material Quantity/ (kg)	Seeding Elevation/(ft)
Triggering	11:00	12:20	NaCl	600	7,500
Fattening	-	-	-	-	-
Attacking	15:05	16:55	NaCl	600	
			Urea	400	

Area of Operation

- Target Area – Maskeliya (Maussakelle & Castlereagh Catchment)
- Air distance – 40 NM (Ratmalana to Maskeliya)



Before the Seeding

Day 01 [March 22, 2019]

- 7.2 mm rainfall to Maussakelle from 4.00 pm to 4.30 pm

➤ Before the Seeding



➤ After the Seeding



Rainmaking Trial Operations - Summery

Date	No of Sorties	Seeding Material Qty.	Outcome
22 Mar 19	02	NaCl 600kg NaCl 600kg Urea 400kg	7.5 mm rain
23 Mar 19	02	NaCl 1000kg 2 nd - Abundant	Rain in elsewhere
24-25 Mar 19	Nil	-	-
26 Mar 19	01	NaCl 900kg	Nil
27-29 Mar 19	Nil	-	-



Conclusion & Recommendations

Conclusion

- Operation could perform only in two days due to the average relative humidity was quite low.
- Result of the operation day was quite promising and it was possible to force the rain into the small catchments area.
- Since the target area is quite small and located in a valley of 7,000-8,000 feet height effecting on the development of the cloud that is moving.
- Cloud seeding was conducted with some steps only using one flight.
- It is necessary to seed the cloud with more than 1 step by adjusting the amount of seeding substance of each step to be suitable.
- Rainmaking evaluation was carried out by using rainfall data monitored by rain gauges and by visual observation of officers in the area.

Recommendations received

- Establish a team of rainmaking consist of 2 aircrafts with the help of personnel from CEB and Meteorological Department.
- Record data of weather condition, upper-air, and cloud formation and rainfall in each period of time of year and analyze continuously for effective rainmaking planning
- In the first stage, the rainmaking evaluation is carried out by using rainfall data monitored by rain gauges and by visual observation of officers in the area.
- In the next stages, rainmaking evaluation should be carried out by using data of weather radar.

Thank you...
