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LAMPIRAN

Lampiran 1. Data pemakaian volume air kompleks perumahan Tonasa 1

No.	Tanggal	Voi	No.	Tanggal	Voi	No.	Tanggal	Voi
1	01/07/2024	562	48	17/08/2024	506	95	03/10/2024	422
2	02/07/2024	557	49	18/08/2024	453	96	04/10/2024	536
3	03/07/2024	551	50	19/08/2024	496	97	05/10/2024	451
4	04/07/2024	531	51	20/08/2024	428	98	06/10/2024	504
5	05/07/2024	527	52	21/08/2024	475	99	07/10/2024	453
6	06/07/2024	506	53	22/08/2024	413	100	08/10/2024	411
7	07/07/2024	554	54	23/08/2024	466	101	09/10/2024	484
8	08/07/2024	611	55	24/08/2024	412	102	10/10/2024	397
9	09/07/2024	625	56	25/08/2024	541	103	11/10/2024	513
10	10/07/2024	614	57	26/08/2024	463	104	12/10/2024	556
11	11/07/2024	546	58	27/08/2024	554	105	13/10/2024	441
12	12/07/2024	536	59	28/08/2024	494	106	14/10/2024	447
13	13/07/2024	516	60	29/08/2024	521	107	15/10/2024	435
14	14/07/2024	498	61	30/08/2024	527	108	16/10/2024	424
15	15/07/2024	435	62	31/08/2024	434	109	17/10/2024	426
16	16/07/2024	522	63	01/09/2024	390	110	18/10/2024	418
17	17/07/2024	495	64	02/09/2024	502	111	19/10/2024	389
18	18/07/2024	525	65	03/09/2024	473	112	20/10/2024	447
19	19/07/2024	474	66	04/09/2024	501	113	21/10/2024	458
20	20/07/2024	516	67	05/09/2024	423	114	22/10/2024	431
21	21/07/2024	417	68	06/09/2024	502	115	23/10/2024	427
22	22/07/2024	537	69	07/09/2024	414	116	24/10/2024	455
23	23/07/2024	441	70	08/09/2024	459	117	25/10/2024	428
24	24/07/2024	542	71	09/09/2024	400	118	26/10/2024	549
25	25/07/2024	453	72	10/09/2024	557	119	27/10/2024	434
26	26/07/2024	490	73	11/09/2024	452	120	28/10/2024	492
27	27/07/2024	420	74	12/09/2024	524	121	29/10/2024	501
28	28/07/2024	464	75	13/09/2024	411	122	30/10/2024	444
29	29/07/2024	411	76	14/09/2024	503	123	31/10/2024	463
30	30/07/2024	446	77	15/09/2024	414	124	01/11/2024	532
31	31/07/2024	416	78	16/09/2024	388	125	02/11/2024	423
32	01/08/2024	538	79	17/09/2024	415	126	03/11/2024	407
33	02/08/2024	518	80	18/09/2024	508	127	04/11/2024	506
34	03/08/2024	490	81	19/09/2024	446	128	05/11/2024	502
35	04/08/2024	413	82	20/09/2024	494	129	06/11/2024	590
36	05/08/2024	492	83	21/09/2024	485	130	07/11/2024	458
37	06/08/2024	402	84	22/09/2024	520	131	08/11/2024	508
38	07/08/2024	504	85	23/09/2024	417	132	09/11/2024	419
39	08/08/2024	422	86	24/09/2024	482	133	10/11/2024	537
40	09/08/2024	526	87	25/09/2024	394	134	11/11/2024	448
41	10/08/2024	458	88	26/09/2024	468	135	12/11/2024	530
42	11/08/2024	547	89	27/09/2024	543	136	13/11/2024	496
43	12/08/2024	426	90	28/09/2024	528	137	14/11/2024	576
44	13/08/2024	474	91	29/09/2024	437	138	15/11/2024	538
45	14/08/2024	409	92	30/09/2024	371	139	16/11/2024	430
46	15/08/2024	444	93	01/10/2024	403	140	17/11/2024	506
47	16/08/2024	456	94	02/10/2024	496	141	18/11/2024	412

Lampiran 1. Data pemakaian volume air kompleks perumahan Tonasa 1 (Lanjutan)

No.	Tanggal	Vol	No.	Tanggal	Vol	No.	Tanggal	Vol
142	19/11/2024	521	159	06/12/2024	598	176	23/12/2024	631
143	20/11/2024	442	160	07/12/2024	615	177	24/12/2024	638
144	21/11/2024	523	161	08/12/2024	606	178	25/12/2024	647
145	22/11/2024	546	162	09/12/2024	593	179	26/12/2024	612
146	23/11/2024	480	163	10/12/2024	558	180	27/12/2024	602
147	24/11/2024	542	164	11/12/2024	542	181	28/12/2024	592
148	25/11/2024	419	165	12/12/2024	533	182	29/12/2024	513
149	26/11/2024	516	166	13/12/2024	571	183	30/12/2024	615
150	27/11/2024	535	167	14/12/2024	581	184	31/12/2024	608
151	28/11/2024	542	168	15/12/2024	576			
152	29/11/2024	515	169	16/12/2024	606			
153	30/11/2024	572	170	17/12/2024	624			
154	01/12/2024	583	171	18/12/2024	578			
155	02/12/2024	538	172	19/12/2024	588			
156	03/12/2024	525	173	20/12/2024	523			
157	04/12/2024	537	174	21/12/2024	628			
158	05/12/2024	633	175	22/12/2024	612			

Lampiran 2. Program komputasi uji asumsi normalitas Kolmogorov-Smirnov

```
# dataset
data <- read.csv("G:/My Drive/SKRIPSI/SKRIPSI/dataairvol1.csv", header = TRUE,
sep = ",")
# fase 1
Xj1 <- data$Volume[1:123]
# Uji Kolmogorov-Smirnov untuk fase 1
ks_test_f1 <- ks.test(Xj1, "pnorm", mean(Xj1), sd(Xj1))
print(ks_test_f1)

# fase 2
Xj2 <- data$Volume[124:184]
# Uji Kolmogorov-Smirnov untuk fase 2
ks_test_f2 <- ks.test(Xj2, "pnorm", mean(Xj2), sd(Xj2))
print(ks_test_f2)
```

```
> data <- read.csv("G:/My Drive/SKRIPSI/SKRIPSI/dataairvol1.csv", header = TRUE, sep = ",")
> # fase 1
> xj1 <- data$Volume[1:123]
> # Uji Kolmogorov-Smirnov untuk fase 1 (uji terhadap distribusi normal)
> ks_test_f1 <- ks.test(xj1, "pnorm", mean(xj1), sd(xj1))
> print(ks_test_f1)
```

Asymptotic one-sample Kolmogorov-Smirnov test

```
data: xj1
D = 0.079109, p-value = 0.4247
alternative hypothesis: two-sided
```

```
> # fase 2
> xj2 <- data$Volume[124:184]
> # Uji Kolmogorov-Smirnov untuk fase 2 (uji terhadap distribusi normal)
> ks_test_f2 <- ks.test(xj2, "pnorm", mean(xj2), sd(xj2))
> print(ks_test_f2)
```

Asymptotic one-sample Kolmogorov-Smirnov test

```
data: xj2
D = 0.091561, p-value = 0.686
alternative hypothesis: two-sided
```

Lampiran 3. Program komputasi *Average Run Length* peta kendali MGC dengan simulasi Monte Carlo

```

# Load library
library(ggplot2)
library(dplyr)
library(tidyr)
library(progress)

# Fungsi untuk simulasi ARL MGC
simulate_ARL_mixed_GWMA_CUSUM <- function(k_Y, q, alpha, h_Y, delta, n_sim=10000,
max_run=10000, stop_threshold=500) {
  run_lengths <- numeric(n_sim)

  pb <- progress_bar$new(
    format = " Simulasi delta :delta [:bar] :percent ETA: :eta",
    total = n_sim, clear = FALSE, width = 60
  )

  for (sim in 1:n_sim) {
    pb$tick(tokens = list(delta = delta))

    t <- 0
    GCplus <- 0
    GCmin <- 0
    in_control <- TRUE
    X_history <- numeric()

    while (in_control && t < max_run) {
      t <- t + 1
      X_t <- rnorm(1, mean = delta, sd = 1)
      X_history <- c(X_history, X_t)

      if (t == 1) {
        Yt <- X_t
      } else {
        sum_term <- sum(sapply(1:t, function(j) (q^((j-1)^alpha) - q^(j^alpha)) *
X_history[t-j+1]))
        Yt <- sum_term + q^(t^alpha) * 0 # Mean awal = 0
      }

      Qt <- sum(sapply(1:t, function(j) (q^((j-1)^alpha) - q^(j^alpha))^2))

      Kt <- k_Y * sqrt(Qt)
      Ht <- h_Y * sqrt(Qt)

      GCplus <- max(0, (Yt - Kt) + GCplus)
      GCmin <- max(0, -(Yt + Kt) + GCmin)

      if (GCplus > Ht || GCmin > Ht) {
        in_control <- FALSE
      }
    }

    run_lengths[sim] <- ifelse(t < max_run, t, max_run)
  }

  return(mean(run_lengths))
}

# Parameter
alpha <- 0.10
k_Y <- 0.5
q <- 0.75
h_Y <- 6.22
delta_values <- seq(0, 2.05, by = 0.05) # Variasi delta dari 0.00 hingga 2.00 dengan jarak
0.05
n_sim_main <- 1000
stop_threshold <- 500

# Simulasi dan penyimpanan hasil
start_time <- Sys.time()
results <- data.frame(delta = numeric(), ARL = numeric())

for (delta in delta values) {

```

```
    arl <- simulate_ARL_mixed_GWMA_CUSUM(k_Y, q, alpha, h_Y, delta, n_sim = n_sim_main,
stop_threshold = stop_threshold)

    results <- rbind(results, data.frame(delta = delta, ARL = arl))

    cat(sprintf("Delta = %.2f, ARL = %.2f\n", delta, arl))
}

end_time <- Sys.time()

# Simpan hasil
write.csv(results, "ARL_GWMA_CUSUM_results9.csv", row.names = FALSE)

# Menampilkan waktu eksekusi
cat(sprintf("Total waktu simulasi: %.2f menit\n", as.numeric(difftime(end_time, start_time,
units = "mins"))))
```

Output pada Lampiran 4, Lampiran 5, lampiran 6, Lampiran 7

Lampiran 4. Average Run Length peta kendali MGC dengan $k = 0.5$ dan $q = 0.25$ pada $ARL_0 \approx 500$

δ	α								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	h_y								
	5.58	6.07	6.51	6.84	7.05	7.19	7.25	7.29	7.29
0.00	648.0	499.5	498.2	498.9	498.5	472.9	498.8	493.3	498.1
0.05	579.3	440.2	432.1	391.2	499.4	446.4	450.2	457.8	438.0
0.10	480.6	337.3	266.3	330.7	324.5	357.6	295.3	323.0	356.5
0.15	263.6	236.5	233.6	228.2	272.0	221.6	253.6	279.8	242.5
0.20	233.0	155.0	145.2	149.4	179.9	171.6	137.4	168.5	174.4
0.25	152.8	115.4	112.8	122.3	126.3	123.0	110.5	130.6	129.3
0.30	90.9	80.5	76.6	78.4	85.0	81.8	91.0	72.7	72.4
0.35	78.5	60.5	62.0	64.3	57.7	72.2	66.7	75.2	58.0
0.40	52.4	46.7	49.5	46.5	45.6	44.4	46.8	45.9	51.0
0.45	46.0	39.0	32.9	41.8	39.9	38.0	40.2	38.0	40.3
0.50	39.6	35.8	28.0	34.2	31.8	30.0	34.9	29.3	30.7
0.55	31.0	24.7	24.8	28.6	25.7	26.9	27.5	26.5	25.1
0.60	24.9	22.8	22.7	23.5	23.1	22.4	21.8	23.9	22.4
0.65	22.6	18.8	22.1	19.2	17.8	16.7	20.9	21.6	19.9
0.70	20.7	17.5	17.8	19.2	16.5	17.1	16.5	19.0	16.5
0.75	16.5	17.0	15.7	16.4	15.9	17.5	15.6	17.4	15.9
0.80	14.4	12.8	14.0	13.6	12.9	13.8	14.2	14.5	14.2
0.85	14.6	13.0	12.9	12.8	13.3	13.0	13.7	12.7	12.4
0.90	12.0	11.1	11.7	11.8	11.6	12.8	11.7	11.9	11.2
0.95	11.1	10.5	11.2	12.0	10.5	10.3	10.7	10.9	11.9
1.00	10.3	9.9	10.0	9.5	9.6	10.6	10.0	10.1	10.5
1.05	10.4	9.5	9.6	9.4	9.3	8.6	9.4	9.2	9.6
1.10	8.4	9.2	9.3	8.8	8.6	8.4	8.1	9.3	9.0
1.15	8.5	7.7	8.1	8.7	9.0	8.5	8.2	8.1	8.6
1.20	7.8	7.7	7.5	8.6	7.8	7.1	7.8	8.2	7.8
1.25	7.4	6.7	7.4	8.0	7.5	8.1	7.5	7.4	7.2
1.30	6.8	7.1	7.7	7.6	7.0	7.2	7.0	7.0	7.0
1.35	6.8	6.6	6.8	6.4	7.2	7.1	7.2	6.6	6.9
1.40	6.7	5.9	6.7	6.3	6.7	6.4	6.4	6.5	6.5
1.45	6.5	6.2	6.0	6.2	6.1	6.5	6.0	6.0	6.2
1.50	5.4	5.4	5.6	6.2	6.5	6.0	6.4	5.8	5.9
1.55	5.7	5.5	5.5	5.5	5.7	5.6	6.0	5.7	5.6
1.60	5.3	4.9	5.3	5.9	5.1	5.5	5.5	5.2	5.8
1.65	5.1	5.1	5.4	5.2	5.4	5.6	5.3	5.3	5.1
1.70	4.7	5.0	4.9	5.3	4.8	5.2	5.4	5.0	4.9
1.75	5.2	5.0	4.8	4.7	4.8	5.2	5.0	5.3	4.8
1.80	4.6	4.6	4.7	4.8	4.9	5.1	4.8	4.9	4.9
1.85	4.4	4.3	4.7	4.6	4.7	4.8	4.9	4.7	4.4
1.90	4.5	4.5	4.5	4.5	4.4	4.5	4.4	4.5	4.6

δ	α								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	h_y								
	5.58	6.07	6.51	6.84	7.05	7.19	7.25	7.29	7.29
1.95	4.3	4.2	4.2	4.4	4.4	4.4	4.3	4.4	4.3
2.00	3.9	4.1	4.1	4.4	4.2	4.3	4.4	4.2	4.4

Lampiran 5. Average Run Length peta kendali MGC dengan $k = 0.5$ dan $q = 0.50$ pada $ARL_0 \approx 500$

δ	α								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	h_y								
	5.93	7.07	8.35	9.56	10.46	11.03	11.29	11.38	11.32
0.00	499.5	499.4	454.5	434.8	498.2	498.8	499.9	499.5	500.0
0.05	410.9	378.6	359.6	365.3	448.9	450.8	394.0	393.2	468.9
0.10	331.7	295.2	234.6	298.5	355.8	299.8	315.9	286.2	300.7
0.15	208.7	188.7	149.8	201.6	207.9	184.7	180.7	209.5	201.7
0.20	146.5	128.9	144.9	113.7	117.1	116.7	130.0	139.4	126.8
0.25	112.7	82.6	89.4	93.7	84.6	84.3	95.5	90.1	80.9
0.30	70.2	71.9	68.8	66.7	71.6	63.7	65.9	72.1	63.5
0.35	57.7	48.3	45.8	44.7	45.2	51.3	56.7	54.3	58.0
0.40	48.4	40.3	40.2	39.8	38.5	39.2	42.5	48.3	43.1
0.45	31.4	32.9	35.9	32.0	30.0	36.2	34.6	38.9	35.6
0.50	30.0	26.1	28.7	27.1	34.2	29.3	28.8	23.8	26.1
0.55	24.5	23.9	25.1	24.2	25.5	25.5	25.3	27.2	26.9
0.60	22.9	19.3	22.5	21.0	21.2	21.6	22.6	22.9	23.4
0.65	18.4	19.9	19.4	19.3	20.5	20.8	21.0	18.0	18.9
0.70	15.7	17.3	19.4	18.2	16.7	17.3	17.7	17.2	15.8
0.75	15.6	14.4	15.3	15.9	16.7	14.3	16.3	15.5	17.0
0.80	14.2	12.7	13.6	13.5	13.8	14.7	14.5	14.6	13.6
0.85	11.0	11.6	12.4	12.3	13.1	14.7	13.5	14.0	13.3
0.90	11.1	11.0	11.4	12.3	12.6	13.0	12.5	12.4	12.3
0.95	9.0	10.0	10.7	11.7	12.5	12.2	11.6	11.1	11.5
1.00	8.5	9.5	9.9	10.8	11.3	10.9	12.0	11.9	10.7
1.05	7.9	9.3	9.4	10.0	10.4	10.5	10.0	10.2	10.2
1.10	7.8	8.6	8.7	9.1	9.6	9.9	9.8	9.7	9.2
1.15	6.9	8.1	8.2	9.2	9.1	9.1	9.4	9.4	9.8
1.20	6.5	7.2	7.3	8.4	8.3	9.1	9.0	8.8	8.2
1.25	6.3	7.4	7.2	8.5	8.4	8.3	8.9	8.9	8.8
1.30	5.2	6.5	7.6	7.5	8.0	8.1	8.6	8.0	8.1
1.35	6.1	6.2	7.2	7.5	7.6	7.5	7.1	7.6	7.7
1.40	5.7	6.1	6.7	7.1	7.3	6.9	7.4	7.1	7.3
1.45	5.6	5.7	6.5	6.8	7.0	7.7	7.3	7.1	6.9
1.50	4.6	5.5	6.0	6.4	6.2	6.7	7.0	6.9	7.2
1.55	4.6	5.2	6.1	6.1	6.3	6.4	6.4	6.4	6.4
1.60	4.6	4.6	5.6	6.0	6.1	6.4	6.4	6.5	6.1
1.65	4.3	4.5	5.5	5.9	6.1	6.3	6.2	6.1	6.0
1.70	4.1	5.0	5.4	5.6	5.9	5.9	6.1	6.1	6.1
1.75	3.6	4.5	4.8	5.6	5.7	5.8	5.6	5.6	5.6
1.80	3.9	4.2	4.8	5.2	5.4	5.5	5.5	5.6	5.4
1.85	3.5	4.0	4.6	5.0	5.5	5.5	5.5	5.2	5.3
1.90	3.5	4.0	4.4	4.8	5.1	5.4	5.3	5.4	5.1

δ	α								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	h_y								
	5.93	7.07	8.35	9.56	10.46	11.03	11.29	11.38	11.32
1.95	3.3	3.9	4.2	4.9	5.1	5.2	5.4	5.0	5.3
2.00	3.1	3.8	4.4	4.7	4.9	4.8	5.0	5.0	4.9

Lampiran 6. Average Run Length peta kendali MGC dengan $k = 0.5$ dan $q = 0.75$ pada keadaan $ARL_0 \approx 500$

δ	α								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	h_y								
	6.22	8.18	11.12	14.73	14.73	20.58	21.59	21.69	21.03
0.00	498.4	479.4	480.7	498.1	344.3	499.4	443.4	452.7	457.3
0.05	345.8	377.0	318.4	423.4	275.0	323.3	379.0	419.5	376.3
0.10	239.9	233.1	227.1	222.0	175.9	244.7	260.4	251.9	260.4
0.15	170.9	142.4	165.8	151.4	124.8	163.1	154.0	159.6	168.2
0.20	105.1	88.3	113.0	91.0	90.6	115.0	99.3	104.3	112.0
0.25	95.0	83.3	70.5	66.9	65.9	77.7	74.0	76.1	89.3
0.30	60.2	55.3	51.3	57.9	49.0	62.7	56.6	61.5	57.8
0.35	45.0	51.5	43.4	43.6	36.5	45.7	45.3	44.4	49.7
0.40	33.7	35.8	39.4	40.0	36.7	38.0	38.7	38.5	38.2
0.45	28.5	32.8	34.0	32.1	27.5	34.1	34.7	36.8	34.4
0.50	23.6	22.8	24.8	27.1	22.5	29.9	32.1	30.4	27.6
0.55	16.7	21.9	23.3	26.3	22.1	26.5	26.7	26.3	25.5
0.60	18.9	21.1	21.7	21.8	19.6	23.1	24.5	22.7	23.8
0.65	14.1	15.8	18.3	20.1	18.9	22.6	23.1	21.6	22.7
0.70	13.8	14.7	17.2	17.9	14.4	18.6	20.4	19.1	20.4
0.75	9.6	12.4	14.5	16.3	15.8	19.2	19.3	18.3	17.7
0.80	10.2	10.8	12.6	15.1	13.4	16.9	17.5	16.9	16.2
0.85	9.1	9.8	11.8	14.3	13.0	15.5	16.9	15.5	16.2
0.90	6.9	8.8	11.0	13.6	12.2	15.2	15.4	15.0	14.6
0.95	7.5	8.4	11.8	12.3	12.0	14.3	14.8	14.3	14.3
1.00	7.2	8.9	9.8	11.8	9.9	13.6	13.6	13.2	13.5
1.05	5.9	7.4	9.7	10.7	10.7	12.9	13.4	13.0	13.2
1.10	5.2	6.6	9.1	10.5	10.8	12.3	12.1	12.1	12.3
1.15	5.3	6.3	8.5	10.5	8.2	12.1	11.6	11.8	11.4
1.20	4.9	7.0	7.8	9.5	9.0	11.8	11.2	11.6	11.4
1.25	4.5	6.1	7.5	8.7	8.6	10.5	10.8	10.6	10.6
1.30	4.4	5.5	6.5	9.0	7.4	10.3	9.9	10.1	10.7
1.35	4.1	4.8	7.0	8.3	7.7	10.1	10.3	9.9	9.7
1.40	3.6	4.6	5.9	8.1	7.9	9.5	10.1	9.7	9.2
1.45	3.4	4.8	5.9	7.5	7.8	9.1	9.4	9.4	9.1
1.50	3.0	4.2	5.4	6.5	7.2	9.1	9.6	9.3	9.0
1.55	2.6	3.5	5.6	7.2	6.4	9.0	9.3	8.7	8.6
1.60	3.0	3.7	5.2	6.6	6.5	8.9	8.5	8.8	8.5
1.65	2.7	3.5	4.9	6.5	6.2	8.2	8.6	8.5	8.0
1.70	2.6	3.4	4.9	5.8	5.9	8.1	8.2	8.1	7.7
1.75	2.4	2.5	4.4	6.2	5.9	7.7	8.0	8.0	7.7
1.80	1.9	3.5	4.2	5.9	5.3	7.9	7.7	7.8	7.5
1.85	2.4	3.0	3.7	5.8	5.1	7.6	7.6	7.2	7.4
1.90	2.0	2.4	3.8	5.3	5.0	7.2	7.2	7.3	7.5

δ	α								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	h_y								
	6.22	8.18	11.12	14.73	14.73	20.58	21.59	21.69	21.03
1.95	1.9	2.7	4.0	5.2	5.0	6.9	7.1	6.9	6.6
2.00	1.6	2.4	3.7	4.7	5.0	6.8	7.0	7.1	6.8

Lampiran 7. Average Run Length peta kendali MGC dengan $k = 0.5$ dan $q = 0.90$ pada keadaan $ARL_0 \approx 500$

δ	α								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	h_y								
	6.42	8.96	12.23	20.83	29.47	36.98	41.10	41.75	40.57
0.00	240.1	299.1	300.9	443.2	477.8	500.0	480.8	486.1	500.0
0.05	197.7	235.4	239.3	339.5	317.4	381.7	365.1	376.8	392.4
0.10	134.6	151.1	149.5	190.8	208.6	216.5	231.6	237.3	227.1
0.15	90.5	95.3	94.9	129.6	135.5	139.1	146.5	133.8	142.7
0.20	61.2	65.1	68.0	88.9	97.9	96.6	98.8	99.3	107.5
0.25	46.4	46.6	50.3	67.9	73.1	74.7	73.7	76.7	74.5
0.30	32.4	34.6	38.2	53.3	59.0	62.1	61.9	60.9	63.3
0.35	24.8	26.9	30.9	43.2	48.3	53.3	55.0	52.2	54.2
0.40	19.8	21.9	25.5	36.3	41.2	43.8	45.7	45.5	45.4
0.45	15.5	18.2	21.4	32.5	37.2	39.4	39.4	39.6	39.1
0.50	12.9	15.3	18.1	26.4	32.3	36.8	36.0	35.1	35.5
0.55	10.6	13.2	15.8	24.0	28.9	32.5	33.6	32.0	31.4
0.60	9.2	11.2	13.6	21.9	26.4	29.6	30.6	30.2	29.3
0.65	8.0	10.0	12.3	19.4	24.1	27.1	28.0	28.2	27.2
0.70	6.8	8.6	10.9	17.6	23.0	24.7	26.0	26.0	25.7
0.75	6.1	7.8	9.9	15.9	20.3	23.8	24.3	24.2	24.1
0.80	5.2	6.9	9.1	15.1	19.1	22.0	23.2	22.9	22.6
0.85	4.8	6.2	8.2	14.0	17.3	20.9	22.1	21.9	21.1
0.90	4.3	5.8	7.5	12.8	17.4	20.0	20.9	20.6	20.7
0.95	3.9	5.2	6.8	12.1	16.0	19.0	19.9	19.5	19.2
1.00	3.7	4.7	6.4	11.2	15.2	17.9	18.7	18.9	18.6
1.05	3.3	4.4	5.9	10.2	13.9	16.6	17.9	17.7	17.6
1.10	3.0	4.1	5.4	9.8	13.6	16.1	17.2	16.9	16.8
1.15	2.8	3.7	5.0	9.0	12.8	15.3	16.5	16.4	16.2
1.20	2.7	3.5	4.7	8.7	12.2	14.7	16.0	16.0	15.8
1.25	2.4	3.3	4.3	7.7	11.3	14.1	15.0	15.5	15.3
1.30	2.3	3.0	4.1	7.6	11.1	13.5	14.7	14.7	14.6
1.35	2.2	2.8	3.8	7.2	10.3	12.9	14.2	14.3	13.9
1.40	2.1	2.7	3.5	7.0	10.1	12.8	13.5	13.8	13.8
1.45	1.9	2.5	3.3	6.5	9.7	12.0	13.3	13.4	13.1
1.50	1.8	2.4	3.1	5.9	9.1	11.7	12.6	12.8	12.6
1.55	1.7	2.2	2.9	5.8	8.7	11.1	12.2	12.5	12.4
1.60	1.7	2.1	2.7	5.4	8.5	10.7	12.0	12.2	12.1
1.65	1.6	2.0	2.6	4.9	8.0	10.5	11.9	12.1	11.7
1.70	1.5	1.9	2.5	5.0	7.6	10.1	11.3	11.5	11.7
1.75	1.5	1.8	2.4	4.8	7.4	9.9	11.0	11.3	11.3
1.80	1.4	1.8	2.2	4.5	7.0	9.5	10.8	10.9	10.7
1.85	1.4	1.6	2.1	4.1	7.0	9.2	10.5	10.7	10.5
1.90	1.4	1.6	2.0	4.0	6.8	8.9	9.9	10.2	10.3

δ	α								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	h_y								
	6.42	8.96	12.23	20.83	29.47	36.98	41.10	41.75	40.57
1.95	1.3	1.5	1.9	3.8	6.2	8.5	9.7	10.1	10.0
2.00	1.3	1.5	1.8	3.6	6.3	8.4	9.4	9.7	9.6

Lampiran 8. Program komputasi *Average Run Length* Peta Kendali CUSUM

```
library(spc)
k <- 0.5
h <- 5
delta <- seq(0, 2.05, by = 0.05)
arll <- sapply(delta, k=k, h=h, sided="two", xcusum.arl)
arll
```

> arll

```
[1] 465.443506 430.101961 348.649676 262.010634 191.281185
[6] 139.493690 103.061804 77.650756 59.820796 47.148806
[11] 37.996143 31.267309 26.229017 22.386861 19.404036
[16] 17.048326 15.157529 13.616801 12.343692 11.278183
[21] 10.375970 9.603907 8.936863 8.355542 7.844946
[26] 7.393282 6.991174 6.631091 6.306924 6.013676
[31] 5.747218 5.504117 5.281494 5.076920 4.888331
[36] 4.713961 4.552295 4.402022 4.262002 4.131242
[41] 4.008871 3.894122
```

Lampiran 9. Program komputasi *Average Run Length* Peta Kendali GWMA dengan simulasi Monte Carlo

```

# Load library
library(ggplot2)
library(dplyr)
library(progress)

# Fungsi Simulasi Monte Carlo ARL GWMA
simulate_ARL_GWMA <- function(q, alpha, L, Mean, sigma, delta, n_sim=10000, max_run=10000)
{
  run_lengths <- numeric(n_sim)

  pb <- progress_bar$new(
    format = " Simulasi delta :delta [:bar] :percent ETA: :eta",
    total = n_sim, clear = FALSE, width = 60
  )

  for (sim in 1:n_sim) {
    pb$tick(tokens = list(delta = delta))

    t <- 0
    in_control <- TRUE
    X_history <- numeric()

    while (in_control && t < max_run) {
      t <- t + 1
      X_t <- rnorm(1, mean = Mean + delta, sd = sigma)
      X_history <- c(X_history, X_t)

      # Menghitung Yt berdasarkan rumus GWMA
      if (t == 1) {
        Yt <- X_t
      } else {
        Yt <- sum(sapply(1:t, function(j) (q^((j-1)^alpha) - q^(j^alpha)) * X_history[t-
j+1])) + q^(t^alpha) * Mean
      }

      # Menghitung Qt untuk batas kendali
      Qt <- sum(sapply(1:t, function(j) (q^((j-1)^alpha) - q^(j^alpha))^2))

      # Menghitung batas kendali GWMA
      UCL <- Mean + L * sqrt(Qt) * sigma
      LCL <- Mean - L * sqrt(Qt) * sigma

      # Deteksi Out-of-Control
      if (Yt > UCL || Yt < LCL) {
        in_control <- FALSE
      }
    }

    run_lengths[sim] <- ifelse(t < max_run, t, max_run)
  }

  return(mean(run_lengths))
}

# Parameter
q <- 0.50
alpha <- 0.75
L <- 3.079
Mean <- 0
sigma <- 1
delta_values <- seq(0, 2.05, by = 0.05) # Pergeseran mean dari 0 hingga 2
n_sim_main <- 10000

# Simulasi dan penyimpanan hasil
start_time <- Sys.time()
results <- data.frame(delta = numeric(), ARL = numeric())

for (delta in delta_values) {
  arl <- simulate_ARL_GWMA(q, alpha, L, Mean, sigma, delta, n_sim = n_sim_main)

  results <- rbind(results, data.frame(delta = delta, ARL = arl))
}

```

```

    cat(sprintf("Delta = %.2f, ARL = %.2f\n", delta, arl))
  }

end_time <- Sys.time()

# Simpan hasil ke CSV
write.csv(results, "ARL_GWMA_results.csv", row.names = FALSE)

# Menampilkan waktu eksekusi
cat(sprintf("Total waktu simulasi: %.2f menit\n", as.numeric(difftime(end_time, start_time,
units = "mins"))))
"delta", "ARL"
0,499.819085487078
0.05,446.840319361277
0.1,294.393213572854
0.15,204.457085828343
0.2,130.84630738523
0.25,99.6546906187625
0.3,68.748502994012
0.35,46.2195608782435
0.4,38.2654690618762
0.45,33.3373253493014
0.5,26.7445109780439
0.55,22.940119760479
0.6,19.2954091816367
0.65,17.3632734530938
0.7,14.7924151696607
0.75,13.7185628742515
0.8,11.9780439121756
0.85,10.4091816367265
0.9,9.96407185628743
0.95,9.34131736526946
1,7.85828343313373
1.05,7.41516966067864
1.1,6.94610778443114
1.15,6.59880239520958
1.2,6.11177644710579
1.25,5.65069860279441
1.3,5.41516966067864
1.35,4.92015968063872
1.4,4.52295409181637
1.45,4.42115768463074
1.5,4.0499001996008
1.55,3.96407185628743
1.6,3.85828343313373
1.65,3.76447105788423
1.7,3.49500998003992
1.75,3.27544910179641
1.8,3.0938123752495
1.85,2.90219560878243
1.9,2.94810379241517
1.95,2.70858283433134
2,2.60878243512974

```

Lampiran 10. Program komputasi peta kendali CUSUM untuk fase 1 dan fase 2

```

library(ggplot2); library(dplyr)
data <- read.csv("G:/My Drive/SKRIPSI/SKRIPSI/dataairv011.csv")

CUSUM <- function(Xj, miu0, h, k) {
  n <- length(Xj)
  Cplus <- Cmin <- c(0, numeric(n))
  for (i in 1:n) {
    Cplus[i+1] <- max(0, Xj[i] - (miu0 + k) + Cplus[i])
    Cmin[i+1] <- max(0, (miu0 - k) - Xj[i] + Cmin[i])
  }
  data.frame(
    Sample = 1:n, Volume = Xj, Cplus = Cplus[-1], Cmin = Cmin[-1],
    UCL = h, LCL = -h,
    Status = ifelse(Cplus[-1] > h | Cmin[-1] > h, "OOC", "In Control")
  )
}

plot_CUSUM <- function(result, title = "Peta Kendali CUSUM", phase = "Fase 1") {
  ggplot(result, aes(x = Sample)) +
    geom_line(aes(y = Cplus), size = 1) + geom_line(aes(y = Cmin), size = 1) +
    geom_point(aes(y = Cplus, color = Status), size = 2) + geom_point(aes(y = Cmin, color
= Status), size = 2) +
    geom_line(aes(y = UCL), linetype = "dashed", color = "gray30") +
    geom_line(aes(y = LCL), linetype = "dashed", color = "gray30") +
    geom_hline(yintercept = 0, color = "gray50") +
    scale_color_manual(values = c("In Control" = "black", "OOC" = "red"), guide = "none")
+
  labs(
    title = paste(title, "-", phase),
    subtitle = paste("Parameters: Mean =", round(mean(result$Volume), 2),
      ", k =", round(k, 2), ", H =", round(result$UCL[1], 2)),
    x = "Sample Number", y = "CUSUM Statistic",
    caption = paste("Total out-of-control proses:", sum(result$Status == "OOC"),
      "(", round((sum(result$Status == "OOC") / nrow(result)) * 100, 2),
"%)")
  ) +
  theme_minimal() +
  theme(panel.grid.minor = element_blank(),
    panel.border = element_rect(fill = NA, color = "gray80"),
    plot.title = element_text(face = "bold"),
    plot.subtitle = element_text(size = 10),
    plot.caption = element_text(hjust = 0))
}

cat("\n===== FASE 1: ANALISIS ITERATIF CUSUM =====\n")

Xj_fasel <- data$Volume[1:123]
fasel_data <- Xj_fasel
iterasi <- 1
terkendali <- FALSE
excluded_samples <- integer(0)
cusum_iterations_summary <- data.frame()
cusum_iteration_dataframes <- list()
miu0 <- mean(fasel_data)
sigma <- sd(fasel_data)
k <- 0.5 * sigma
h <- 5 * sigma

while (!terkendali) {
  miu0 <- mean(fasel_data)
  sigma <- sd(fasel_data)
  k <- 0.5 * sigma
  h <- 5 * sigma

  result_CUSUM <- CUSUM(fasel_data, miu0, h, k)
  cusum_iteration_dataframes[[iterasi]] <- result_CUSUM

  ooc_indices <- which(result_CUSUM$Status == "OOC")
  ooc_count <- length(ooc_indices)

  cusum_iterations_summary <- rbind(cusum_iterations_summary, data.frame(
    Iterasi = iterasi, Jumlah_Data = length(fasel_data),
    Mean = miu0, StdDev = sigma, k_value = k, h_value = h,
    OOC_Points = ooc_count,
    Status = ifelse(ooc_count > 0, "TIDAK TERKENDALI", "TERKENDALI")
  ))
}

```

```

))

cat("\n=== DATAFRAME LENGKAP HASIL CUSUM ITERASI", iterasi, "===\n")
print(result_CUSUM)

if (ooc_count > 0) {
  cat("- Status: TIDAK TERKENDALI\n")
  cat("- Jumlah titik out-of-control:", ooc_count, "\n")
  cat("- Sampel yang dieliminasi:", paste(ooc_indices, collapse=", "), "\n")

  eliminated_original_indices <- which(Xj_fasel %in% fasel_data[ooc_indices])
  excluded_samples <- c(excluded_samples, eliminated_original_indices)
  fasel_data <- fasel_data[-ooc_indices]

  print(plot_CUSUM(result_CUSUM, paste("Peta Kendali CUSUM (Iterasi", iterasi, ")"),
"Phase 1"))
  iterasi <- iterasi + 1
} else {
  cat("- Status: TERKENDALI\n")
  terkendali <- TRUE
  print(plot_CUSUM(result_CUSUM, "Peta Kendali CUSUM (Final)", "Phase 1"))
}
}

fasel_final_miu0 <- mean(fasel_data)
fasel_final_sigma <- sd(fasel_data)
fasel_final_k <- 0.5 * fasel_final_sigma
fasel_final_h <- 5 * fasel_final_sigma

cat("- Parameter final untuk monitoring:\n")
cat(" - Mean ( $\mu_0$ ):", round(fasel_final_miu0, 4), "\n")
cat(" - Std. Deviation ( $\sigma$ ):", round(fasel_final_sigma, 4), "\n")
cat(" - Nilai referensi (k):", round(fasel_final_k, 4), "\n")
cat(" - Batas kendali (h):", round(fasel_final_h, 4), "\n\n")
cat("\nSummary Iterasi CUSUM Fase 1:\n")
print(cusum_iterations_summary)

cat("\n===== FASE 2: MONITORING CUSUM =====\n")

Xj_fase2 <- data$Volume[124:184]
result_CUSUM_fase2 <- CUSUM(Xj_fase2, fasel_final_miu0, fasel_final_h, fasel_final_k)
cat("\n=== DATAFRAME LENGKAP HASIL CUSUM FASE 2 ===\n")
print(result_CUSUM_fase2)
print(plot_CUSUM(result_CUSUM_fase2, "Peta Kendali CUSUM", "Phase 2 (Monitoring)"))

```

Lampiran 11. Program komputasi peta kendali GWMA untuk fase 1 dan fase 2

```

library(ggplot2)
library(dplyr)
data <- read.csv("G:/My Drive/SKRIPSI/SKRIPSI/dataairvoll.csv", header = TRUE, sep = ",")

# GWMA Functions
hitung_Yt <- function(X, q, alpha, Mean) {
  n <- length(X)
  Yt <- numeric(n)
  for (t in 1:n) {
    if (t == 1) {
      Yt[t] <- (q^(0^alpha) - q^(1^alpha)) * X[t] + q^(1^alpha) * Mean
    } else {
      sum_term <- sum(sapply(1:t, function(j) (q^((j-1)^alpha) - q^(j^alpha)) * X[t-j+1]))
      Yt[t] <- sum_term + q^(t^alpha) * Mean
    }
  }
  return(Yt)
}

hitung_Qt <- function(q, alpha, t) {
  Qt <- sum(sapply(1:t, function(j) ((q^((j-1)^alpha) - q^(j^alpha)))^2))
  return(Qt)
}

GWMA <- function(X, q, alpha, Mean, sigma, L) {
  n <- length(X)
  Yt <- hitung_Yt(X, q, alpha, Mean)
  Qt_values <- sapply(1:n, function(t) hitung_Qt(q, alpha, t))
  UCL <- Mean + L * sqrt(Qt_values) * sigma
  CL <- rep(Mean, n)
  LCL <- Mean - L * sqrt(Qt_values) * sigma
  status <- ifelse(Yt > UCL | Yt < LCL, "OOC", "In Control")
  result_table <- data.frame(
    Sample = 1:n,
    Value = X,
    Yt = Yt,
    Qt = Qt_values,
    UCL = UCL,
    CL = CL,
    LCL = LCL,
    Status = status
  )
  return(result_table)
}

plot_GWMA <- function(result, title = "Peta Kendali GWMA", phase = "Fase 1") {
  ooc_count <- sum(result$Status == "OOC")
  ooc_percentage <- (ooc_count / nrow(result)) * 100

  ggplot(result, aes(x = Sample)) +
    geom_line(aes(y = Yt), color = "black", size = 1) +
    geom_line(aes(y = UCL), linetype = "dashed", color = "darkgray", size = 1) +
    geom_line(aes(y = CL), linetype = "solid", color = "gray50", size = 1) +
    geom_line(aes(y = LCL), linetype = "dashed", color = "darkgray", size = 1) +
    geom_point(aes(y = Yt, color = Status), size = 2) +
    scale_color_manual(values = c("In Control" = "black", "OOC" = "red"), guide = "none")
  +
  labs(
    title = paste(title, "-", phase),
    subtitle = paste("Parameters: q =", round(q, 2), ", alpha =", round(alpha, 2), ", L =", round(L, 2)),
    x = "Sample Number",
    y = "Yt Value",
    caption = paste("Total out-of-control points:", ooc_count, "(", round(ooc_percentage, 2), "%)")
  )
}

```

```

) +
theme_minimal() +
theme(
  panel.grid.minor = element_blank(),
  panel.border = element_rect(fill = NA, color = "gray80"),
  plot.title = element_text(face = "bold"),
  plot.subtitle = element_text(size = 10),
  plot.caption = element_text(hjust = 0)
)
}

# FASE 1: ANALISIS ITERATIF GWMA
Xj_fase1 <- data$Volume[1:123]
fase1_data <- Xj_fase1
iterasi <- 1
terkendali <- FALSE
excluded_samples <- c()

# Parameter awal
q <- 0.90
alpha <- 0.90
L <- 2.840
Mean_awal <- mean(fase1_data)
sigma_awal <- sd(fase1_data)
all_iterations_results <- list()

while (!terkendali) {
  Mean <- mean(fase1_data)
  sigma <- sd(fase1_data)
  result_GWMA <- GWMA(fase1_data, q, alpha, Mean, sigma, L)
  all_iterations_results[[iterasi]] <- result_GWMA

  ooc_indices <- which(result_GWMA$Status == "OOC")
  ooc_count <- length(ooc_indices)

  if (ooc_count > 0) {
    eliminated_original_indices <- which(Xj_fase1 %in% fase1_data[ooc_indices])
    excluded_samples <- c(excluded_samples, eliminated_original_indices)
    fase1_data <- fase1_data[-ooc_indices]
    print(plot_GWMA(result_GWMA, paste("Peta Kendali GWMA (Iterasi", iterasi, ")"), "Fase
1"))
    iterasi <- iterasi + 1
  } else {
    terkendali <- TRUE
    print(plot_GWMA(result_GWMA, "Peta Kendali GWMA (Final)", "Fase 1"))
  }
}

# Simpan parameter fase 1
fase1_final_Mean <- mean(fase1_data)
fase1_final_sigma <- sd(fase1_data)
cat("- Parameter monitoring:\n")
cat(" - Mean:", round(fase1_final_Mean, 4), "\n")
cat(" - Std. Deviation (σ):", round(fase1_final_sigma, 4), "\n")
cat(" - q:", q, ", alpha:", alpha, ", L:", L, "\n")
# FASE 2: MONITORING GWMA
cat("\n=== MONITORING FASE 2 ===\n")
Xj_fase2 <- data$Volume[124:184]
result_GWMA_fase2 <- GWMA(Xj_fase2, q, alpha, fase1_final_Mean, fase1_final_sigma, L)
print(plot_GWMA(result_GWMA_fase2, "Peta Kendali GWMA", "Fase 2 (Monitoring)"))

```

Lampiran 12. Program komputasi peta kendali MGC untuk fase 1 dan fase 2

```

library(ggplot2)
library(dplyr)
data <- read.csv("G:/My Drive/SKRIPSI/SKRIPSI/dataairvoll.csv", header = TRUE, sep = ",")
# MGC-CUSUM Functions
hitung_Yt <- function(X, q, alpha, Mean) {
  n <- length(X)
  Yt <- numeric(n)
  for (t in 1:n) {
    sum_term <- sum(sapply(1:t, function(j) (q^((j-1)^alpha) - q^(j^alpha)) * X[t-j+1]))
    Yt[t] <- sum_term + q^(t^alpha) * Mean
  }
  return(Yt)
}

hitung_Qt <- function(q, alpha, t) {
  Qt <- sum(sapply(1:t, function(j) ((q^((j-1)^alpha) - q^(j^alpha))^2))
  return(Qt)
}

MGC_CUSUM <- function(X, q, alpha, Mean, sigma0, k_Y, h_Y) {
  n <- length(X)
  Yt <- hitung_Yt(X, q, alpha, Mean)
  Qt_values <- sapply(1:n, function(t) hitung_Qt(q, alpha, t))
  Kt <- k_Y * sigma0 * sqrt(Qt_values)
  Ht <- h_Y * sigma0 * sqrt(Qt_values)

  GCplus <- numeric(n + 1)
  GCmin <- numeric(n + 1)
  GCplus[1] <- 0
  GCmin[1] <- 0
  hasil <- character(n)

  for (t in 1:n) {
    GCplus[t + 1] <- max(0, (Yt[t] - Mean) - Kt[t] + GCplus[t])
    GCmin[t + 1] <- max(0, -(Yt[t] - Mean) - Kt[t] + GCmin[t])

    if (GCplus[t + 1] > Ht[t] || GCmin[t + 1] > Ht[t]) {
      hasil[t] <- "OOC"
    } else {
      hasil[t] <- "In Control"
    }
  }

  result <- data.frame(
    Sample = 1:n,
    Value = X,
    Yt = Yt,
    Qt = Qt_values,
    GCplus = GCplus[2:(n + 1)],
    GCmin = GCmin[2:(n + 1)],
    Kt = Kt,
    Ht = Ht,
    UCL = Ht,
    LCL = -Ht,
    Status = hasil
  )

  return(result)
}

plot_MGC <- function(result, title = "Peta Kendali Mixed GWMA-CUSUM", phase = "Fase 1") {
  ooc_count <- sum(result$Status == "OOC")
  ooc_percentage <- (ooc_count / nrow(result)) * 100

```

```

ggplot(result, aes(x = Sample)) +
  geom_line(aes(y = GCplus), color = "black", size = 1) +
  geom_line(aes(y = GCmin), color = "gray50", size = 1) +
  geom_line(aes(y = UCL), linetype = "dashed", color = "darkgray", size = 1) +
  geom_line(aes(y = LCL), linetype = "dashed", color = "darkgray", size = 1) +
  geom_point(aes(y = GCplus, color = ifelse(GCplus > UCL, "OOC", "In Control")), size =
2) +
  geom_point(aes(y = GCmin, color = ifelse(GCmin > UCL, "OOC", "In Control")), size = 2)
+
  scale_color_manual(values = c("In Control" = "black", "OOC" = "red"), guide = "none")
+
  labs(
    title = paste(title, "-", phase),
    subtitle = paste("Parameters: q =", round(q, 2),
                    ", alpha =", round(alpha, 2),
                    ", k_Y =", round(k_Y, 2),
                    ", h_Y =", round(h_Y, 2)),
    x = "Sample Number",
    y = "MGC-CUSUM Value",
    caption = paste("Total out-of-control points:", ooc_count,
                    "(", round(ooc_percentage, 2), "%)")
  ) +
  theme_minimal() +
  theme(
    panel.grid.minor = element_blank(),
    panel.border = element_rect(fill = NA, color = "gray80"),
    plot.title = element_text(face = "bold"),
    plot.subtitle = element_text(size = 10),
    plot.caption = element_text(hjust = 0)
  )
}

# FASE 1: ANALISIS ITERATIF MGC-CUSUM
Xj_fase1 <- data$Volume[1:123]
fase1_data <- Xj_fase1
iterasi <- 1
terkendali <- FALSE
excluded_samples <- c()

# Parameter awal
q <- 0.75
alpha <- 0.10
k_Y <- 0.5
h_Y <- 6.22
Mean_awal <- mean(fase1_data)
sigma0_awal <- sd(fase1_data)

iterasi_results <- data.frame(
  Iterasi = integer(),
  Jumlah_Data = integer(),
  Mean = numeric(),
  Sigma = numeric(),
  Jumlah_OOC = integer(),
  Status = character()
)

all_iteration_dfs <- list()
while (!terkendali) {
  Mean <- mean(fase1_data)
  sigma0 <- sd(fase1_data)
  result_MGC <- MGC_CUSUM(fase1_data, q, alpha, Mean, sigma0, k_Y, h_Y)
  all_iteration_dfs[[iterasi]] <- result_MGC

  ooc_indices <- which(result_MGC$Status == "OOC")
  ooc_count <- length(ooc_indices)
}

```

```

status_proses <- ifelse(ooc_count > 0, "TIDAK TERKENDALI", "TERKENDALI")

iterasi_results <- rbind(iterasi_results, data.frame(
  Iterasi = iterasi,
  Jumlah_Data = length(fasel_data),
  Mean = Mean,
  Sigma = sigma0,
  Jumlah_OOC = ooc_count,
  Status = status_proses
))

if (ooc_count > 0) {
  eliminated_original_indices <- which(Xj_fasel %in% fasel_data[ooc_indices])
  excluded_samples <- c(excluded_samples, eliminated_original_indices)
  fasel_data <- fasel_data[-ooc_indices]
  print(plot_MGC(result_MGC, paste("Peta Kendali Mixed GWMA-CUSUM (Iterasi", iterasi,
  ")", "Fase 1"))
  iterasi <- iterasi + 1
} else {
  terkendali <- TRUE
  print(plot_MGC(result_MGC, "Peta Kendali Mixed GWMA-CUSUM (Final)", "Fase 1"))
}
}

fasel_final_Mean <- mean(fasel_data)
fasel_final_sigma0 <- sd(fasel_data)

# FASE 2: MONITORING MGC-CUSUM
cat("\n=== MONITORING FASE 2 ===\n")
Xj_fase2 <- data$Volume[124:184]
result_MGC_fase2 <- MGC_CUSUM(Xj_fase2, q, alpha, fasel_final_Mean, fasel_final_sigma0,
k_Y, h_Y)
print(plot_MGC(result_MGC_fase2, "Peta Kendali Mixed GWMA-CUSUM", "Fase 2 (Monitoring)")

```